ARCTIC FISH HABITAT USE INVESTIGATIONS: NEARSHORE STUDIES IN THE ALASKAN BEAUFORT SEA, SUMMER 1988

by

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ABSTRACT

During summer 1988, the Ocean Assessments Division Alaska Office conducted a nearshore fish survey in the Beaufort Sea. The primary objective of the study was to collect arctic char for genetic stock identification research being conducted for OCSEAP by the U.S. Fish and Wildlife Service (RU 682). Purse seining provided an offshore dimension to the inshore fyke-net collections by the FWS. The secondary objective of the study was to investigate habitat use by fish in the nearshore zone. A 150-m-long purse seine was the primary sampling gear used, it was supplemented with gillnet sampling when conditions did not allow seining. Hydrographic profiles obtained in conjunction with seine sets allowed investigation of fish habitat use in coastal, transitional, and marine water masses.

Over 3,500 fish were captured in combined purse seine and gillnet catches. Capelin and arctic cod were numerically dominant, occurring with greater frequency in catches from transitional waters. Anadromous species were captured in coastal waters and, of these, only arctic char and arctic cisco were collected far offshore. It appears that coastal water overlaying transitional water provides a physical habitat structure enabling char and arctic ciscoes to use the latter cooler, more saline habitat to forage on small marine fish (cods and capelin). Length frequency distributions, weight-length relationships, and condition factors (Kn) of captured fishes are presented. Stock identification analyses of arctic char collected in early August from Stefansson Sound indicated Sagavanirktok and Canning River fish to be proportionately most abundant. Arctic char from the eastern Beaufort Sea and Canada were also represented in the coastal sampling.

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INTRODUCTION

Background

In 1986 the Outer Continental Shelf Environmental Assessment Program (OCSEAP) initiated an investigation of the coastal migratory behavior of arctic char (Research Unit 682). In 1986 and 1987 the research focused on the genetic characterization of arctic char populations in North Slope drainages of Alaska and western Canada. This work was freshwater oriented and designed to determine if genetic differences between major stocks exist. Arctic char were sampled in rivers between Icy Cape (Chukchi Sea) and the Mackenzie River (Canada), Populations were abundant only in the drainages east of and including the Colville River.

Analysis for genetic similarity in the baseline samples demonstrated enough variation in certain protein structures for stock identification to river-of-origin (Everett and Wilmot 1987; Everett et al. 1988). This result led to a widespread study of coastal char migrations in 1988. The coastal study involved cooperative research between the National Oceanic and Atmospheric Administration {NOAA) and the U.S. Fish and Wildlife Service (FWS). Tissues from the captured char would be sent to the FWS for genetic stock identification (GSI) analysis. Stock identification would be used to examine the migrations and intermixing of North Slope arctic chars during the summer months. This report describes the results of the NOAA arctic fish study; the FWS is preparing separate reports to OCSEAP on GSI objectives of the research.

Arctic char were selected for stock identification research by OCSEAP and the Minerals Management Service (MMS) because: (1) the total population size is relatively small; (2) the species may be limited in coastal range by the availability of relatively warm brackish waters; (3) the species is of subsistence and recreational value; and (4) the species had been identified as one meriting "special concern" through the Outer Continental Shelf (OCS) leasing process. The distinct character of North Slope populations suggests little straying of spawners and concomitant low interchange of genetic material among stocks. It also implies that the time required by a stock to recover from a population-level impact would be lengthened by lack of immigrant spawners from other streams. Additionally, and more germane to this report, if the river-of-origin of arctic char can be determined with a reasonable degree of confidence, stock-specific risk assessments associated with coastal developments may be possible and more cost-effective than traditional mark-recapture studies with similar objectives.

Current State of Knowledge

The development of oil fields in the Alaskan Beaufort Sea has occurred exclusively within the coastal zone. Seismic exploration for commercial offshore reserves, while possible, is limited by open water accessibility and summer sea ice conditions. Most exploration wells have been drilled in water depths less than 22 m (Padron 1988). Today, oil production in the Endicott area of Prudhoe Bay represents the seaward extent of "offshore" activities. If oil fields are to be developed in deeper waters, their exploitation will require an improved technological capability to operate safely and economically in this ice-impacted environment (Norton and Weller 1984; Padron 1989).

Historically, most arctic fisheries research has been designed to address environmental concerns associated with leasing of state and federal lands for oil and gas exploration and development. A lack of OCS development activities in the Beaufort Sea in concert with logistical difficulties of operating in ice have delayed fishery investigations in deepwater (>50 m) habitats. Several comprehensive reviews and synthesis documents are available that describe the coastal fish community of the Beaufort Sea (Craig and McCart 1976; Barnes et al. 1984; Becker 1987; Winters et al. 1988; Meyer and Johnson 1989; Norton 1989). The literature reveals that most research has been conducted in shallow brackish waters found during summer months along the mainland coast. In areas where extensive nearshore surveys have been conducted, seasonal trends in relative abundance of dominant fish are evident. However, robust population estimates are unavailable; this lack reflects, in part, the fact that most research has been for environmental assessment rather than resource management purposes. Reliable population information will not be forthcoming without long-term commitment for research to this end.

The major environmental issues associated with exploration and development of arctic oil reserves have focused on the protection of subsistence resources and lifestyles. With the discovery of oil in Prudhoe Bay in 1968, anadromous fish species in coastal waters of the central Beaufort Sea have received much attention. Elsewhere along the coast, oil and gas exploration activities have prompted fishery investigations in the Canadian Beaufort Sea (e.g., Kendel et al. 1975; Bond 1989; Hopke 1989), and in lagoons and embayments adjacent to the Arctic National Wildlife Refuge (e.g., see Truett 1983; Fruge et al. 1989). Thus far, little research has been conducted west of Harrison Bay. In 1988, the North Slope Borough conducted a nearshore fish survey in Dease Inlet in preparation of a fishery management plan for Barrow.

The existing arctic fish database is essentially one-dimensional in space, reflecting the inshore concentration of research. Consequently, many onshore–offshore features of fish migration, habitat use, and general ecology are unknown. Only a few American studies have possessed an offshore sampling component (Craig et al. 1982; Frost and Lowry 1983; Moulton and Tarbox 1987; Houghton and Whitmus 1988; and Fruge et al. 1989) although various reports describe the results of incidental offshore fishing (e.g., Craig and Haldorson 1981). Most of these data have been incorporated into existing synthesis documents.

Most fishery sampling in the Alaskan Beaufort Sea has been done using passive gears (e.g., fyke nets and gillnets) with relatively long (12-24 hr) set periods. The resultant "time-integrated" catch data are not amenable to correlation with physical phenomena of brief temporal and small spatial scales, such as the passage of fronts, eddies, and wind-driven upwelling events, which are prevalent in North Slope coastal waters. Such short-lived phenomena are important because they influence the local distributions, movements, and other daily activities of fish and their prey. Reliable information about the environmental history of the fish is necessary for realism in habitat preference models. If predictive models (e.g., to study population response to habitat modifications) are to be developed, a more detailed record of fish movements along known environmental gradients (e.g., thermal and salinity histories) will be required.

The Coastal Fish Community

The arctic fish community is noted for its low species diversity with many species occurring at the northern limits of their ranges. At present 62 species have been identified from the Alaskan Beaufort Sea (Craig 1984). By comparison, more than 100 species have been collected in the Canadian Arctic. More species will likely be described in Alaska when marine habitats are more thoroughly studied.

The coastal fish community can be grouped into freshwater (restricted to river estuaries), anadromous, and marine categories. In this report, we are concerned primarily with the latter two groups. Common names of fishes used herein are as reported by Bailey et al. (1970). The taxonomic status of several arctic species (and groups) remains unresolved (Craig 1989a). Of particular interest to this study, the western Arctic-Bering Sea char is thought by some to be *Salvelinus alpinus,* and others to be the northern form of Dolly Varden, *S. malma.* A recent meristic analysis of Alaskan chars by Morrow (1980) supports the latter contention.

Craig (1984) provides a list of fishes collected in the Alaskan Beaufort Sea. Arctic cod (*Boreogadus saida*), arctic flounder (*Liopsetta glacialis*), fourhorn sculpin (*Myoxocephalus quadricornis*), and Pacific herring (*Clupea harengus*) are widely distributed and abundant marine species. Sixteen species of anadromous fish are listed but only nine are described as principal species of the southern Beaufort Sea. These include: arctic char (*S. alpinus*), arctic and least ciscoes (*Coregonus autumnalis* and *C. sardinella*), broad and humpback whitefish (C. *nasus* and C. *pidschian*), inconnu (*Stenodus leucichthys*), rainbow smelt (*Osmerus mordax*), and pink and chum salmon (*Oncorhynchus gorbuscha* and *O. kisutch*).

Temporal and areal differences in the composition of coastal fish communities (i.e., species present, frequency of occurrence, size and age of species) have been commonly reported (e.g., Winters et al. 1988). These differences probably reflect local variations in species' ranges and habitats. However, it is noteworthy that several species seem to be well represented in all catches. Arctic cisco, least cisco, arctic char, fourhorn sculpin, and arctic cod composed 91-98$% of the species caught at five locations along the coast between Simpson Lagoon and the Yukon Territory (Carey et al. 1987). In a fisheries study of the Canadian coast between Herschel Island and the Blow River, least cisco, arctic cisco, arctic char, fourhorn sculpin, rainbow smelt (= boreal smelt), and humpback whitefish (= lake whitefish) comprised 95% of the total catch (Kendel et al. 1975).

The results of intensive sampling conducted in the 1986 Endicott Environmental Monitoring Program identify the dominant fish of Prudhoe Bay (Glass et al. 1987). The following list shows the rank order of abundance of species in marine, anadromous, and freshwater categories and in the total catch (the arctic grayling, a freshwater species, was ranked #12 overall):

Marine		
Arctic cod	(*Boreogadus saida*)	1
Fourhorn sculpin	(*Myoxocephalus quadricornis*)	3
Saffron cod	(*Eleginus gracilis*)	4
Arctic flounder	(*Liopsetta glacialis*)	7
Snailfish	(*Liparis* spp.)	9
Capelin	(*Mallotus villosus*)	13
Anadromous		
Arctic cisco	(*Coregonus autumnalis*)	2
Least cisco	(*C. sardinella*)	5
Broad whitefish	(*C. nasus*)	6
Ninespine sticklebacks	(*Pungitius pungitius*)	8
Boreal/rainbow smelt	(*Osmerus mordax*)	10
Round whitefish	(*Prosopium cylindraceum*)	11
Humpback whitefish	(*C. pidschian*)	14

Irvine and Meyer (1989; Table III-7) demonstrate temporal changes in dominance of species at a given fyke net location. In Simpson Lagoon during 1977, fourhorn sculpin were heavily dominant, followed by arctic cisco and arctic cod. During 1978, arctic cod were numerical dominants and fourhorn sculpin comprised the majority of the remaining catch.

Moulton and Tarbox (1987) derived estimates of fish densities from hydroacoustic sampling at fixed locations and transects in Prudhoe Bay. In July, calculated densities were 0.7-10.5 fish/10^4 m^3. In August, mean transect densities were 55.6 fish/10^4 m^3, while fixed location densities were 15.8 fish/10^4 m^3. The range of calculated fish densities during the August survey period was O-328.6 fish/10^4 m^3. Some indication of the variability of fish density over a few days at a given location can be derived from data presented in Moulton and Tarbox (1987; Table 2). During the period 28 August-1 September, the mean density and the standard deviation about the mean were 55.6 fish and 86.8 fish/10^4 m^3, respectively, on transect 2 (n = 15; total volume sampled = 49 x 10^4 m^3).

Marine Fishes

Some 40 species of marine fish have been collected in the Alaskan Beaufort Sea (Craig 1984). The marine fishes of the coastal waters include pelagic and benthic groups; the former are dominated by arctic cod and the latter by fourhorn sculpin and arctic flounder. Catch data suggest that the pelagic fishes are patchily distributed and often in large schools, while the benthic fishes seem to be more uniformly dispersed. Fourhorn sculpin and arctic flounder are euryhaline and occur inshore throughout the open-water period.

Historically, fourhorn sculpin made up a large percentage of nearshore fish catches reported from Prudhoe Bay and elsewhere in the Beaufort Sea. Arctic flounder dominated catches at Beaufort Lagoon in 1982 (Griffiths 1983) and 1985 (Wiswar 1986). Gallaway and Britch (1983) noted that peak catches of arctic cod near the Sagavanirktok River delta were related to late season increases in salinity. The annual abundance of capelin and saffron cod is variable but both species are frequently captured along the coast.

Frost and Lowry (1983) captured 19 species, or species groups, of fishes in 35 otter trawls made at several offshore stations across the Beaufort Sea. Only one station was in water depths exceeding 200 m. Arctic cod (Lowry and Frost 1981), Canadian eelpout (*Lycodes polaris*), and twohorn sculpin (*Icelus bicornis*) made up 65% of all fish captured. The results of under-ice gill netting indicated some arctic cod remain in shallow waters of Simpson Lagoon during winter but were more abundant in deeper water catches some 80 km north of Stefansson Sound (Craig et al. 1982). Houghton and Whitmus (1988) found arctic cod and post-larval capelin to be in greatest abundance in offshore sampling conducted in Prudhoe Bay during August 1988.

Anadromous Fishes

Anadromous fishes--mainly coregonids and arctic char--are regionally important because they comprise the bulk of North Slope subsistence, commercial, and sport harvests. The annual subsistence harvest of these fish by North Slope villagers is roughly 190,000 pounds (Craig 1989b), while the annual commercial harvest of arctic and least ciscoes from the Colville River has ranged from about 10,000 to 70,000 fish (Gallaway et al. 1989). Sport angling effort on arctic char is increasing in rivers east of Prudhoe Bay (e.g., the Hulahula River) due to the growth of recreational tourism in northern Alaska. Arctic cisco, least cisco, broad whitefish, and arctic char are dominant target species of commercial, subsistence, or developing sport fisheries.

The size of the Alaskan North Slope arctic char population is uncertain. Historical data from aerial surveys (FWS 1977) would suggest a population exceeding 35,oOO fish. The summer 1985 fyke net catch of over 20,000 char in the Prudhoe Bay area (Cannon et al. 1986) is indicative of a considerably larger population. The limited amount of information regarding the availability of instream overwintering habitat suggests a sustainable population more on the order of a few hundred thousand fish.

Anadromous arctic char spend most of their lives in freshwater habitats. Arctic char are common residents of at least ten rivers east of and including the Colville River. These rivers possess perennial freshwater springs and headwaters in the Brooks Range thought to be requisites for overwintering. In addition, the springs provide relatively warm, oxygenated waters that are used for rearing, reproduction, and incubation. Not all arctic char are anadromous. Certain populations or small segments of populations remain freshwater residents throughout their lives (Armstrong and Morrow 1980).

Anadromous char migrate to sea at the time of, or shortly after, spring breakup. Anadromous char range in length (FL) from 10 to 70 cm and have an average lifespan of about 10 years *(Craig* 1989a). At breakup, larger fish precede smaller fish in timing of coastal migrations. This probably reflects the larger fishes' greater ability to cope with strong currents and to move quickly offshore to areas where foods are most abundant in June. Although small numbers of fish smelt at age 1+, most are 3 to 4 years old before first entering seawater (Cannon et al. 1986; Craig 1989a).

The coastal migration is metabolically driven over a 1.5- to 2-month period. Norwegian researchers (Berg and Berg 1989) have related sea temperature to growth and timing of migration in anadromous arctic char. They report that the highest average daily growth rates occur in late June and early July despite warmer sea temperatures later in summer. The most favorable environmental conditions for arctic char in the Beaufort Sea may, therefore, be early in the open-water sea with older fish fulfilling energy requirements for growth and spawning at an earlier date than younger fish.

By mid-August ripening spawners begin returning to river habitats, several weeks in advance of non-reproducing members of the population. According to Craig (1989b), approximately 50% of the arctic char population spawns for the first time at age 7, after which spawning occurs in alternate years. Spawning occurs in October and November in areas that may, or may not, coincide with overwintering habitats.

Several authors (e.g., Craig and McCart 1976; Craig et al. 1985) have indicated that sea-going North Slope arctic char have a limited ocean range. The most distant offshore capture of arctic char in the Alaskan Beaufort Sea we are aware of is 18 km offshore (Bendock 1977; Craig 1989a). However, Armstrong and Morrow (1980) reported northern Dolly Varden char captures as far as 420 km off the coast of Kamchatka. Among the dominant anadromous forms, the arctic char is believed to be the most tolerant of increased salinities and colder water temperatures (Ross 1988).

Tag recapture data show that arctic char are capable of traveling as much as 250-300 km during summer excursions and that transboundary migrations occur (Craig 1984). Craig and Griffiths (1981) estimated coastal migration rates of 3-5 km/d during summer periods of active feeding. Feeding movements are thought to reflect responses to local environmental conditions and prey densities. Later in the open-water season, much higher speeds (approximately 75 km/d) are possible as fish return to overwintering sites (Craig and Haldorson 1981). By comparison, Pearcy and Fisher (1988) have reported migration rates of 80 km/d for 140-mm-FL juvenile coho salmon off Oregon and Washington coastlines in warmer water environments.

Arctic cisco disperse during summer throughout the nearshore waters of the Beaufort Sea coast. These fish are thought to be of a single stock or multiple stocks

originating in the Mackenzie River (Gallaway et al. 1983; Bickham 1989; Troy 1989). There are five known spawning "areas" in the Mackenzie River, and others may exist. The coastal range of arctic cisco overlaps that of the closely related Bering cisco (*Coregonus laurettae*) *in* the Harrison Bay area of the Beaufort Sea. Anadromy in arctic ciscoes differs from other arctic anadromous fishes in that soon after hatching, most juveniles migrate to sea. The mechanisms involved with their subsequent coastal migrations are poorly known, but thought to include passive transport. The small size of ciscoes (30 mm FL) leaves them at least somewhat dependent on prevailing currents (Fechhelm and Fissel 1988). It has been hypothesized that as much as 20-30 percent of the arctic cisco from the Mackenzie River population may be transported into Alaskan waters (Gallaway et al. 1983).

The total number of Mackenzie River fish recruited into Alaskan waters fluctuates widely from year to year. Apparently, recruitment success is related to summer wind conditions, with relatively strong recruitment observed in years when easterly winds predominate (Moulton 1989). Other factors, including aspects of the various years' spawning success and differential mortality in early life stages, must influence the abundance of small fish moving into Alaskan waters. In Alaska, overwintering sites have been located in deep pools of the Sagavanirktok and Colville deltas (Craig 1989a; Schmidt et al. 1989).

It is clear that Alaskan waters provide important summer and winter habitats for immature arctic ciscoes. Fish mature at ages 7-9 (Craig 1989a) and spawning occurs in the fall. The limited tag returns indicate that ripening fish return to the Mackenzie River during the summer of the year preceding first spawning (Moulton 1989). While many features of the life history of the arctic cisco are becoming known (cf. Bickham 1989), the biological contribution of Alaskan-reared fish to the spawning population and fisheries of the Mackenzie River remains unknown.

Least cisco are widely distributed in Alaskan coastal waters and are common along the Beaufort Sea coast (except in the vicinity of Barter Island) in summer months (Craig 1989a). Major centers of coastal dispersal are the Mackenzie and Colville rivers. Least cisco are uncommon or absent in Alaskan rivers east of the Sagavanirktok River and it has been suggested that the species' habitat requirements for overwintering are not met in mountain-fed streams in the eastern Alaskan Beaufort Sea (Craig 1989a). Both anadromous and lake spawning populations are present west of the Colville River. Schmidt et al. (1983) reported least ciscoes to be the most abundant anadromous species west of Prudhoe Bay.

The age of first migration to sea varies in the least cisco and is thought to be similar to that of the broad whitefish. Age-at-size data indicate first migrations in Age 1-, 2-, and 3-year fish (Craig 1989a). Least ciscoes enter coastal waters during spring breakup and return to fresh water by mid-September. Spawning occurs in fall and 50% of the population spawns for the first time at 10-11 years (Craig 1989a). Known overwintering areas are located in deltas and deep river areas of the Colville, Mackenzie, and other rivers (Schmidt et al. 1989). An analysis of age distributions at the deltaic wintering sites demonstrates the presence of older fish (i.e., 5-13 years; Schmidt et al. 1989). *Younger* fish also may have been present but none were captured by the size-selective gear used.

The coastal range of broad whitefish extends from Kuskokwim Bay in the southeastern Bering Sea north- and eastward to the Perry River, Northwest Territories. In the Alaskan Beaufort Sea, Flaxman Island approximates the eastern limit of the coastal range of broad whitefish originating in western North Slope streams. The lack of broad whitefish in mountain-fed rivers of the North Slope again suggests that these environments are in some way inhospitable to the species (Craig 1989a).

Broad whitefish display variable periods of freshwater residency priorto migrating to sea for the first time. The species is intolerant of any but very low salinity conditions and summer dispersals are restricted by the availability of very low salinity water adjacent to the coast (Griffiths and Gallaway 1982). One result of this restriction is that their diet is the most disparate of the dominant anadromous forms; freshwater invertebrates (drift and benthic aquatic organisms) are of great nutritional importance in this species' diet. Broad whitefish were among the most commonly captured fishes at Sagavanirktok River wintering sites in 1985-86 and they were present in both fresh and brackish water locations (Schmidt et al. 1989).

Over the past 20 years many researchers have studied the nearshore fish communities along mainland and inner barrier island coasts. Less information is available describing fish occurrence in water depths exceeding 2 m. It is therefore difficult to evaluate the importance of the outer portion of the brackish warm-water zone, or the adjacent purely marine habitats, to arctic fish (see Craig 1989a). Available data from offshore sampling suggests open water expanses (e.g., mid-lagoonal waters) may be a more valued habitat (by virtue of the total area involved)to fish than commonly thought (Craig and Griffiths 1981; Wiswar and West 1986).

Anadromy involves the alternate occupation of freshwater and sea habitats by fish. This usage is linked in time and space by their seasonal migrations. Arctic conditions, especially availability of finds, argue for evolution of a simple diadromous life history (noncompetitive selection) to maximize population fitness in response to environmental conditions originating outside the gene pool (Gross 1987). Craig (1989a) concludes that in the arctic, anadromous fish display several unambiguous K-selected traits (adaptations to predictable seasonal conditions) including long life spans, slow growth, delayed maturity, iteroparity, and low recruitment success. In large part these adaptations are related to the reduced temporal opportunity for feeding (energy acquisition) and this is further reflected in the strategy of seasonal migrations to the coastal sea where food is more plentiful.

several species of amphipods (*Onisimus glacialis, Pontoporeia affinis, Ampherusa glacialis,* and *Gammarus setosus*) and mysids (*Mysis relicts* and *M. litoralis*) comprise the bulk of coastal prey for arctic char and ciscoes (Craig and Haldorson 1981; Craig 1984). Apparent preferences for a particular prey species have been used, in part, to depict the partitioning of estuarine habitat by arctic char, ciscoes, and broad whitefish (Figure 1). In summer arctic char feed on a wider prey spectrum than the other species. Evidently larger arctic char cross an ecological threshold leading to piscivory (Craig 1989a) and feed on small fish, such as arctic cod and liparid snailfish, as well as amphipods, copepods, and the mysid M. *relicts*. The arctic and least ciscoes appear less tolerant of cooler temperatures and intermediate salinities, feeding primarily on amphipods and *M. relicts*. Broad whitefish occur in shallow delta waters and feed primarily on amphipods, and terrestrial- and riverine-derived sources of invertebrate foods.

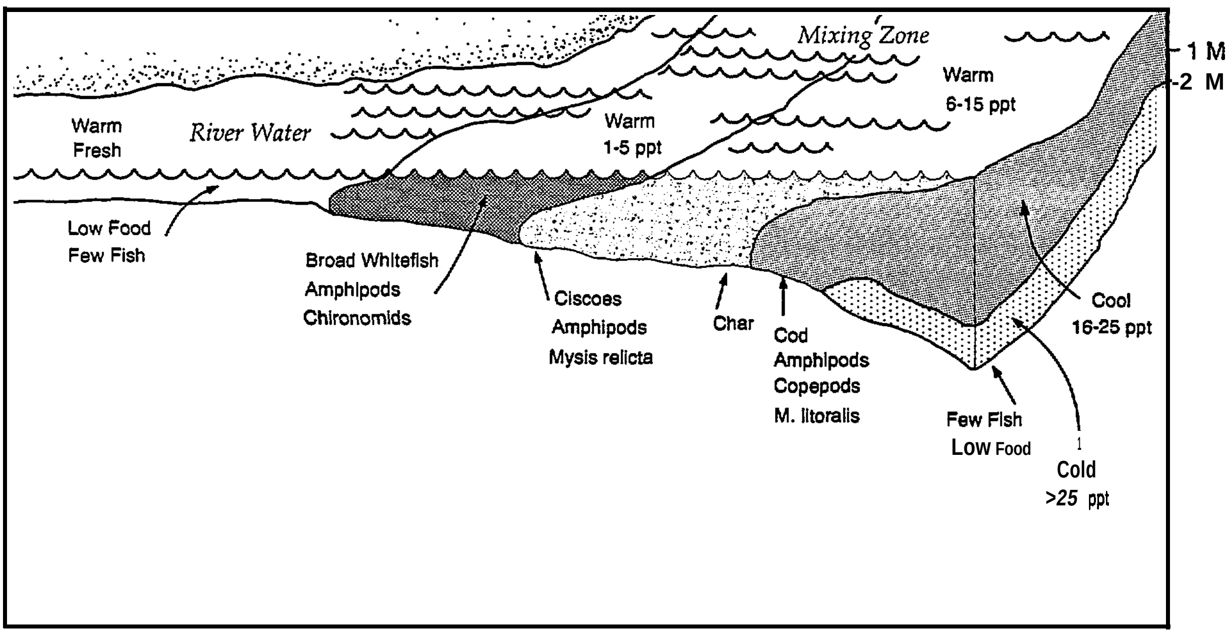


Figure 1.--General fish use of habitat in the nearshore central Beaufort Sea (redrawn from U.S. Environmental Protection Agency 1988).

Environmental Setting

The following paragraphs present an overview of the physical and biological attributes of the coastal Alaskan Beaufort Sea. We have emphasized topics pertaining to our study, thus the discussion is restricted to selected aspects of the dominant fish species, the coastal environment, and the open-water period. Readers desiring additional information are referred to Barnes et al. (1984), Becker (1987), Winters et al. (1988), Meyer and Johnson (1989), and NorInn (1989).

Physical Environment

In summer the shorefast ice melts and pack ice recedes northward, resulting in an area of open water fringing the coast. The extent of the open water varies from year to year; in some years it may be expansive, in others, so little as to effectively impede coastal navigation. Large-scale climatic factors play a role in the annual variability.

The open-water season usually begins about mid- to late June, being triggered by warming temperatures, prolonged insolation, and runoff from streams. The pattern of breakup is to some degree predictable, occurring first at the mouths of large rivers and in lagoons, then proceeding elsewhere. River runoff typically peaks in late May and early June. River discharge patterns vary in the region; tundra streams display a brief, "impulse-like" discharge cycle (in response to rainfall and melting snow), while mountain-fed rivers tend to have less peaked, more prolonged discharges (Robertson 1987). About 80% of the annual flow of the Kuparuk River occurs in June, as compared to 35% of the Sagavanirktok River's (Figure 2; see U.S. Geological Survey, various years). The fresh water flows far offshore over the shorefast ice from all rivers and streams and hastens nearshore ice melt.

The spate of runoff in the early part of the open-water season forms a coastal band of freshened water in the shallow coastal waters that is essentially unbroken for some 750 km from Point Barrow eastward into Canada. The band may extend 20-25 km offshore near large rivers (Craig 1984) and 2-10 km along other shorelines (Craig 1989a). This dynamic and ephemeral habitat is typically continuous in early summer and discontinuous later. The relatively warm water of the coastal band is thought to confer benefits to fish in the form of abundant prey and accelerated metabolic processing of ingested food. Both are requisites for building the energy reserves needed for overwintering, and, in the case of mature fish, spawning that year.

A strong front is established between brackish and adjacent marine waters in the early part of summer. The front is constantly eroding, weakening, and re-establishing itself in response to wind mixing and upwelling processes along the coast. As summer advances, declining runoff and turbulent mixing processes contribute to the progressive erosion of the brackish water mass. The first major marine intrusion usually occurs about the third week in July (B. Gallaway, LGL, pers. commun.). The coastal band becomes discontinuous and much reduced in areal extent in late summer.

Moulton and Tarbox (1987) have described two distinctive water masses occurring in the Prudhoe Bay region during summer: *coastal water* (temperature 2–9°C, salinity 6-27 ppt); and *marine water* (temperature below -1°C, salinity 28-32 ppt). These water masses are frequently separated by a pycnocline of variable (1-6 m) thickness containing a mixture of the two primary water masses. Marine waters presumably are derived from the surface waters of the offshore Beaufort Sea, which have temperatures and salinities of –1.4°C to –1.7°C and 28-32 ppt, respectively (Ostenso 1966).

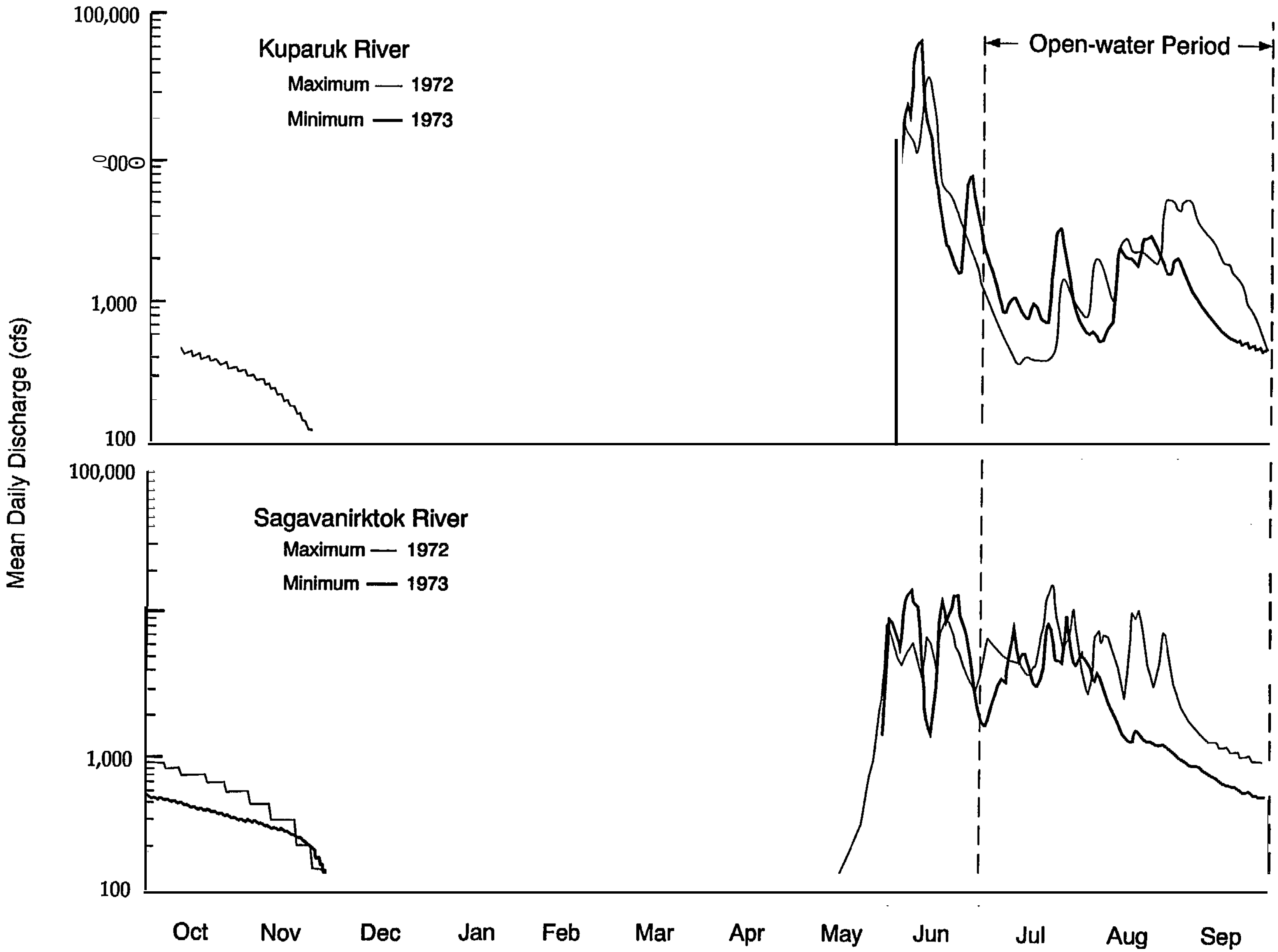


Figure 2.—Kuparuk River and Sagavanirktok River hydrographs (modified from Carlson et al. 1977).

Meteorological observations from Barter Island and Oliktok Pt. (Figure 3) illustrate the dominance of easterly winds in the coastal zone during the open-water season. The more bimodal distribution of winds at Barter Island reflects the steering effect of the Brooks Range, which is near the coast in the eastern portion of the region. Scalar mean wind speeds are about 5 m/see during summer, but peak speeds often exceed 15 m/sec during storm events. The strongest winds are usually westerlies.

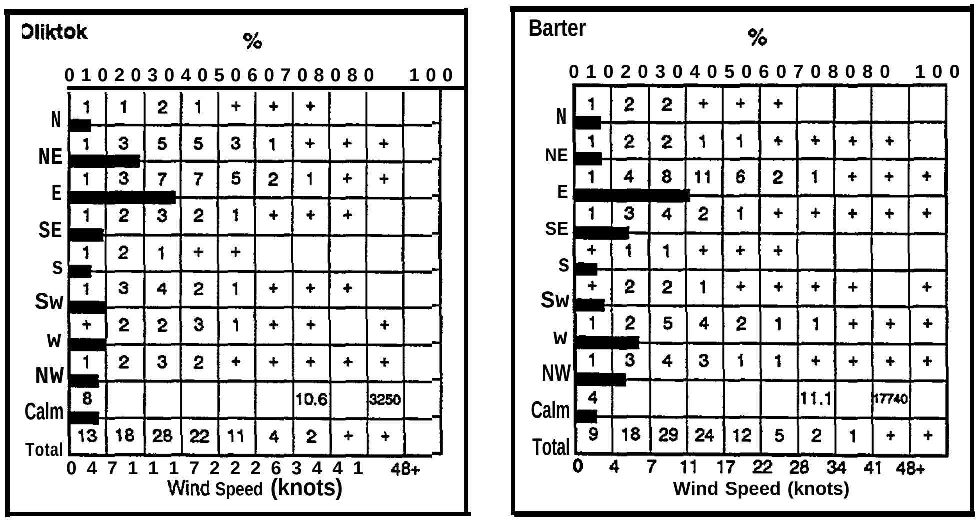
Colonell and Niedoroda (1989) note that wind stress, horizontal pressure gradients, and tides are the driving forces of circulation in coastal waters. Astronomical tides are mixed semidiurnal, range from 10 to 30 cm in amplitude, and due to the small amplitudes have a negligible influence on currents and turbulent mixing in coastal waters. Tidal effects are more pronounced in shallower and confined lagoons (Hale 1989). Winds, especially those associated with storm conditions, are the dominant phenomena driving currents and altering water property distributions over shallow parts of the continental shelf of the Beaufort Sea. Storm surge runups to 3.4 m have been recorded (Wise and Leslie 1988). Coastal currents usually flow westward, reflecting the dominant wind patterns. However, reversals often occur when the winds shift to westerlies. Wind-driven surface current speeds are typically 15-20 cm/sec (Hachmeister 1987).

Currents and thermohaline structure in the coastal waters may change rapidly in response to fluctuating winds and other phenomena. In addition, the responses of coastal waters to winds are affected by the character of their thermohaline structures. Where pronounced stratification occurs in the water column, as is common early in the open-water season, the response is greater than when water column stratification is weak or absent. In the former case, the surface waters are in essence fictionally uncoupled from the deeper waters and momentum transferred from the wind is effectively confined there. If stratification is weak or absent, momentum is distributed through the water column and bottom friction opposes the water's response to wind forcing. Thus, for a given wind speed, surface current speeds will be higher under stratified conditions than under unstratified conditions.

Fish Habitat Utilization

The nature of habitat use by fish in the coastal waters of the central Beaufort Sea has been intensively studied in recent years. Patterns of habitat use by the more common species and life stages are becoming evident aud an understanding of the underlying biological and physical factors is emerging.

Food availability.--The heavy utilization of the brackish water band by the coastal fish community is partly related to the ready availability of crustacean prey that seasonally colonize shallow waters (Broad et al. 1979). Craig (1989a) estimated that during the open-water season, mysids and amphipods are roughly two orders of magnitude more abundant in coastal waters than are aquatic invertebrates in adjacent freshwater habitats. The spatial dimensions of the two habitats studied by Craig (1989a) are similar,



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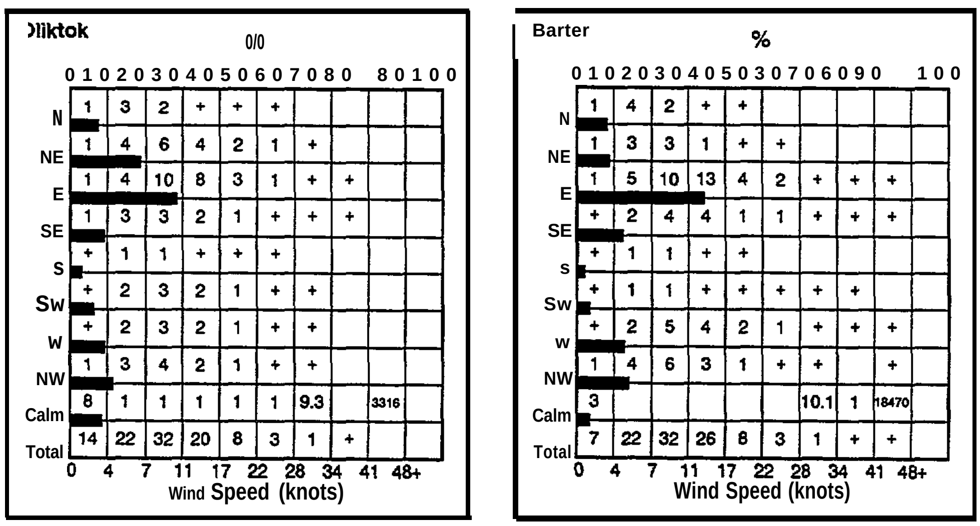

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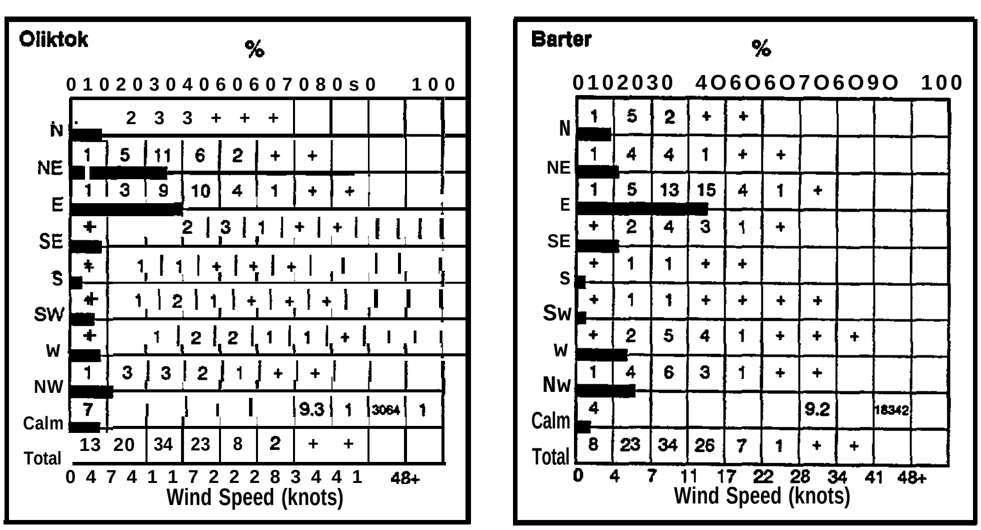

July

Figure 3.--Wind **speed** and direction. Bars represent frequency of winds observed **from** each **direction.** Printed **figures** represent frequency of wind speeds observed **from** each direction (redrawn **from** Brewer et al. 1988).

about 1,500 km^2 each. The large difference in food abundance thus argues well for the anadromous strategy that has evolved in many North Slope coregonid and char life cycle patterns.

Physiological needs.--Another factor promoting fish utilization of brackish water habitats is their relative warmth in comparison to marine waters. Moulton and Tarbox (1987) suggested that poikilotherm fish seek warm waters to accelerate metabolic processes and thereby allow them to maximize the accumulation of energy reserves during the short summer feeding period. This hypothesis is given weight by Craig's (1989a) observation that while North Slope anadromous fish grow 1-2 cm per year, most of this growth occurs in summer.

Salinity also affects fish use of coastal habitats. Certain marine species, such as arctic cod, appear to become more prevalent inshore as the brackish water habitat becomes more saline in late summer. Conversely, freshwater fish such as grayling are intolerant of saline water and are rarely found far from estuaries. There is some evidence of least cisco overwintering in the Canadian Beaufort near Tuktoyaktuk Harbor and off the Mackenzie River delta; however, no marine overwintering has been observed in Alaskan waters (Schmidt et al. 1989). A continuous supply of fresh water from the Mackenzie River may be the key to the ciscoes wintering in the estuary.

Houghton et al. (1989) recently completed an arctic fish habitat use analysis based on a 4-year database composed of some 180,000 records from Prudhoe Bay and vicinity. Fyke net catch per unit of effort (CPUE, standardized to 24hr set periods) was examined in relation to temperature and salinity data collected at the time the nets were cleared of their catches. Several cohorts of four fish species--arctic char, arctic cisco, least cisco, and broad whitefish--were evaluated. The general trend evident from the work is that all four species preferred waters having salinities of 0-20 ppt and temperatures of 4-12°C during the early July to mid-August time interval.

Fechhelm et al. (1989) examined short-term movement patterns of least cisco and arctic cisco in the vicinity of the West Dock causeway during 1981-84; they found an apparent dependence of movement around the causeway on prevailing wind direction and water properties. Eastward dispersals of small least and arctic ciscoes from the Colville River were blocked by adverse hydrographic conditions resulting from prolonged easterly winds.

Reproductive state.---Habitat use may be affected by the reproductive state of the fish. Gallaway and Britch (1983) noted that movements of spawning and non-spawning individuals of the same species may differ during the same season. The movements of non-spawners may represent feeding forays that are altered by responses to the environmental variables, while those of the spawners are characterized by very directed movements with little apparent influence of environmental attributes other than those necessary to locate home streams.

Size relationships---There appears to be a relationship between fish size and habitat association in certain of the species present in North Slope coastal waters. Work by Moulton et al. (1985) and Houghton et al. (1989) suggests that the larger arctic char and arctic cisco occur more frequently in colder, more saline waters than do smaller fish. Again, these differences in habitat use may stem from size-dependent physiological requirements, timing of entry into seawater, size-related rates of movement, and different food preferences. The bimodal distributions observed in the length frequencies of some species in coastal collections (e.g., broad whitefish) may relate to density-dependent mortality at overwintering sites.

Spatial patterns---The species richness of the coastal fish community is greatest in the vicinity of the large river estuaries (Craig and McCart 1976). Distinctive patterns of fish use of coastal habitats were evident during studies carried out at Simpson Lagoon in the late 1970s. There, the largest gillnet catches consistently occurred within 100 m of the mainland shoreline, with progressively smaller catches along island inner shorelines, in mid-lagoon, adjacent to island outer shorelines, and offshore (Craig and Haldorson 1981). A similar pattern of anadromous fish distribution showing decreasing abundance with increasing distance from shore has been reported in Camden Bay (Fruge et al. 1989). Craig (1984) noted that, among the anadromous fish, least ciscoes and broad and humpback whitefishes were uncommon anywhere but near the mainland shore. In contrast, arctic ciscoes and arctic char were more broadly distributed in the brackish waters, the char being the most abundant anadromous species seaward of barrier islands. Arctic cod are strongly ice-associated (Sekerak 1982). This was the only species captured at a winter station 175 km offshore in the Beaufort Sea (Craig et al. 1982).

Some benthic marine fishes appear to be associated with particular kinds of bottom substrates, while others have no apparent preferences. Snailfish and the fish doctor (*Gymnelis viridis*) apparently prefer rocky bottom-kelp habitats; they were observed by divers at the Boulder Patch in Stefansson Sound (Dunton et al. 1982). The ubiquity of fourhorn sculpin in a variety of habitats (Craig and Haldorson 1981) suggests the species has no strong substrate associations.

The migratory patterns of anadromous species are genetically-cued in time and space to the spawning requirements of the populations. Ripening arctic char that have dispersed while feeding to the western Beaufort Sea return to the mountain streams of the eastern North Slope, while the coregonids return to the tundra streams of the western North Slope and the Mackenzie River system (Craig 1989a). The absence of least cisco and whitefishes in the eastern Beaufort was attributed more to the lack of spawning populations in nearby rivers than to the absence of suitable habitat in coastal waters (Griffiths 1983).

Temporal aspects.--The timing of use of coastal marine habitats varies among species and, for a species, among life stages, years and locales, being controlled by the interplay of numerous extrinsic and intrinsic factors--several of which are mentioned above. The timing of annual migratory movements of anadromous fishes between freshwater and marine habitats is predictable; however, relatively little is known about their migration patterns in the marine environment. It is theorized that coastal foraging entails random wandering (3-6 km/d) as fish seek environmental optima.

Quantitative data on fish movement patterns in the Alaskan Beaufort Sea have been accumulating rather slowly, in part because of the low marine recapture rates typically occurring in mark-recapture studies. Fechhelm et al. (1989) observed eastward-moving waves of least cisco shortly after breakup in the vicinity of Prudhoe Bay. These fish presumably were coming from the Colville River. During three years least cisco tagged in the Arctic National Wildlife Refuge (ANWR) were recaptured in the fall in the East Channel of the Colville River, suggesting either that Colville stocks disperse eastward to the former area during summer or that some adult fish from the Mackenzie River stocks move westward and overwinter in the Colville (Moulton and Field 1989). Recaptures of marked small arctic cisco in front of the Sagavanirktok delta showed significant directed movements of those fish to the west during the July-September period, with very strong movements in the latter month (Gallaway and Britch 1983).

Some information on fish movement rates along the coast has resulted from the tagging. Craig and Haldorson (1981) estimated that net movements of migrating anadromous fishes are some 3-6 km/day. Fechhelm et al. (1989) noted that a large arctic cisco recovered at Kaktovik had traveled at least 170 km in 7 days, which equates to a swimming speed of at least 1 km/hr. Higher rates have been estimated for anadromous fish during late season return migrations (Craig and Haldorson 1981) and 3 km/hr may indicate the upper limit of sustained migratory speeds.

Onshore-offshore migrations of demersal fishes, such as fourhorn sculpin, from shallow to deeper waters occur in fall; they are driven by the formation of shorefast ice. At the time of maximum ice thickness in late winter, essentially all habitat less than about 2 m deep is inaccessible to them. Many deeper, isolated depressions containing unfrozen water in coastal lagoons and river deltas become unsuitable for fish in late winter due to anoxia and/or hypersalinity resulting from brine rejection during ice formation.

The Issues

The geographic coincidence of valued fish, “critical” habitat, and perturbing anthropogenic activities has prompted a large number of biological and ecological studies by industry and government alike. Of these, an extraordinary amount of scientific attention has focused on the coastal oceanography and fisheries ecology of the central Beaufort Sea. At issue is how causeways affect coastal habitats and their use by anadromous fish (e.g., migration, summer feeding). The emphasis of monitoring research has been on habitats and their use by fish in the Endicott and Prudhoe Bay areas. The resolution of the problem of relating potential modifications in coastal habitat to population health, while often discussed, is not possible within the context of existing information.

There are numerous mechanisms by which populations and fishermen may be adversely affected by North Slope industrialization. Burns and Bennet (1987) identified five categories of possible effects:

1) direct mortality (e.g., from oil spills);

2) habitat destruction (e.g., due to gravel removal from streams);

3) displacement and dislocation by barriers (e.g., from solid fill causeways);

4) changes in access to resources (e.g., adverse habitat alterations); and

5) regulatory barriers affecting harvesting activities (e.g., decreased catch limits due to increasing human use of resources).

All of the above pertain to oil and gas development activities in the Prudhoe Bay area and those contemplated off the ANWR. The 4.4-km West Dock and 7.7-km Endicott causeways at Prudhoe Bay have demonstrably altered local currents, sediment transport, and thermohaline structure within the brackish water zone (Envirosphere 1987; Stringer 1988; Hale and Hameedi 1988; Colonell and Niedoroda 1989). A third, 2-km causeway--Niakuk --has been proposed for the eastern end of Prudhoe Bay.

The individual and cumulative effects of causeways on coastal fish communities present long-standing issues (Craig and Griffiths 1981; Norton 1989). The concerns center on fish passage around the structures and possible adverse habitat changes that may affect population productivity. Habitat modifications (i.e., changes in temperature and salinity regimes) are caused by causeway-induced deflections of currents and entrained waters away from the coast. During easterly winds this sometimes results in an enhanced discontinuity in the brackish coastal band. The discontinuity occurs when marine water is present sufficiently close to shore to be upwelled in the lee of a causeway. The altered thermohaline structure produced by deflection of brackish water offshore is temporally conservative and may persist as much as 65 km downstream of the perturbing structure (Ross 1988).

Petroleum exploration and production activities in the Beaufort Sea also introduce the potential for marine oil spills resulting from blowouts, subsea pipeline failures, human error, or ice-related events. A total of 24 oil spills larger than 1,000 barrels were predicted to occur over the lifetime of OCS Sale 97 and then existing federal and state leases; of those, one was expected to exceed 100,000 barrels (MMS 1988).

OBJECTIVES

In 1988, NOAA's Alaska Office participated in stock identification research (RU 682) on arctic char in the coastal Beaufort Sea. The NOAA participation involved collection of arctic char from offshore areas. The "offshore component" to RU 682 was considered advantageous because (1) it provided greater geographic coverage to the study than was possible from inshore work alone, and (2) it provided additional information on fish habitat use in areas where few data are currently available.

The goal of this study was to improve the information base on arctic fish habitat use by augmenting the meager offshore data. While collection of arctic char was of primary interest, useful information on other species would be obtained. This information can be coupled with OCS oil spill or other development scenarios to evaluate potential effects of the perturbations on fish in the coastal waters. Specific objectives for the FY 88 field work were:

1. Determine the spatial-temporal distributions, relative abundances, habitat associations and degree of intermixing of North Slope arctic char stocks in the coastal waters of the Alaskan Beaufort Sea.

2. Determine the spatial-temporal distributions, distributions, relative abundances, and habitat associations of other dominant coastal fishes of the Alaskan Beaufort Sea.

While the primary objective was being addressed in cooperative research with the FWS, our intent was to investigate the onshore-offshore dimension of anadromous char migratory behavior. Our supposition was that anadromous char occupy the entirety of the coastal brackish water habitat, but do not habitually venture into the colder, more saline marine waters. The offshore survey would complement other coastal sampling programs (e.g., FWS) and furnish a broader spatial perspective of habitat use than heretofore available.

STUDY AREA

Areal Considerations

The study area consisted of the eastern portion of the Alaskan Beaufort Sea coastal zone extending from the Colville River to the Canadian border (Figure 4). Highly variable ice and weather conditions precluded station sampling along predetermined transects and it was therefore necessary to emphasize "areal" sampling within hydrographically-defined coastal, transitional, and marine fish habitats. The study area was subdivided into four "coastal sections" (A = Harrison Bay, B = Stefansson Sound, C = Camden Bay, D = Barter Island-Demarcation Point; Figure 5) to establish priority sampling areas. Although somewhat arbitrary, this partitioning was based primarily on areal proximity to major char-producing rivers of the region (e.g., Colville, Sagavanirktok, Kavik, Canning, Hulahula, Aichilik, Egaksrak, and Kongakut). The coastal area to be surveyed essentially encompassed the known summer range of the species in Alaskan Beaufort waters. Coastal sections B-D (western, central, and eastern portions of the char coastal range) were judged to be of highest sampling priority.

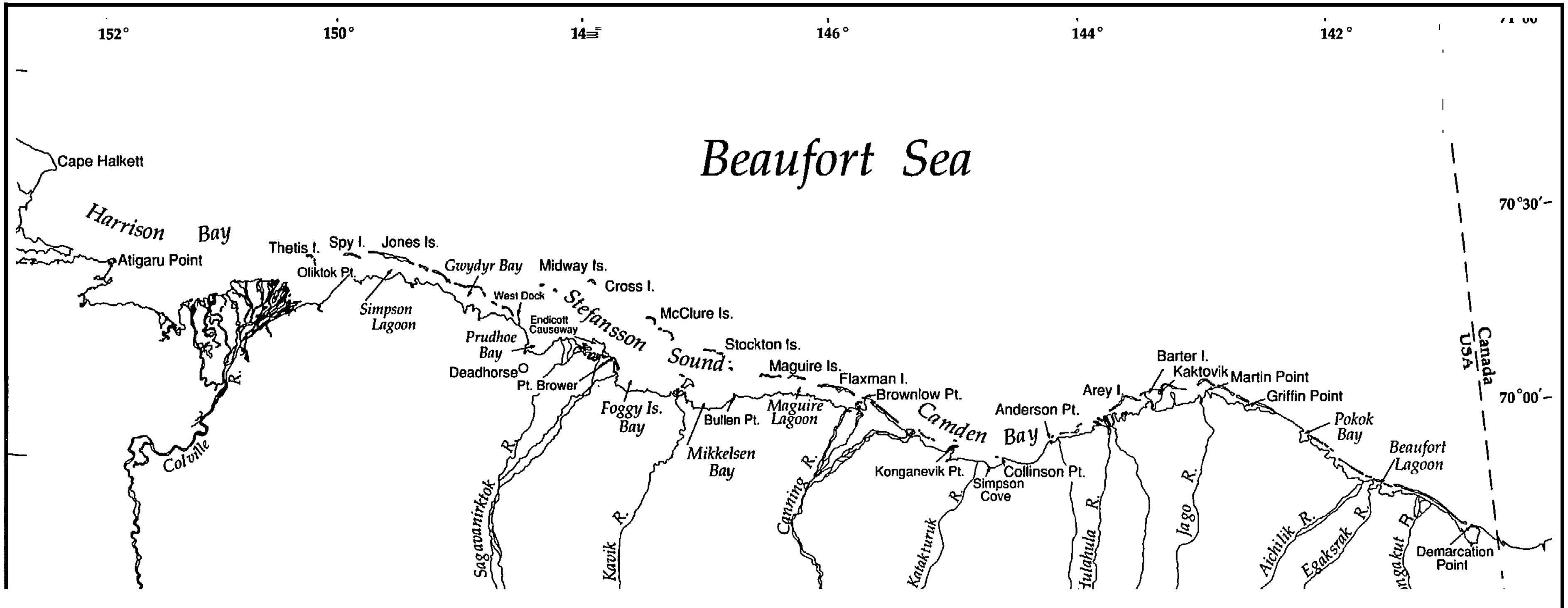

Figure 4.--Beaufort Sea study area.

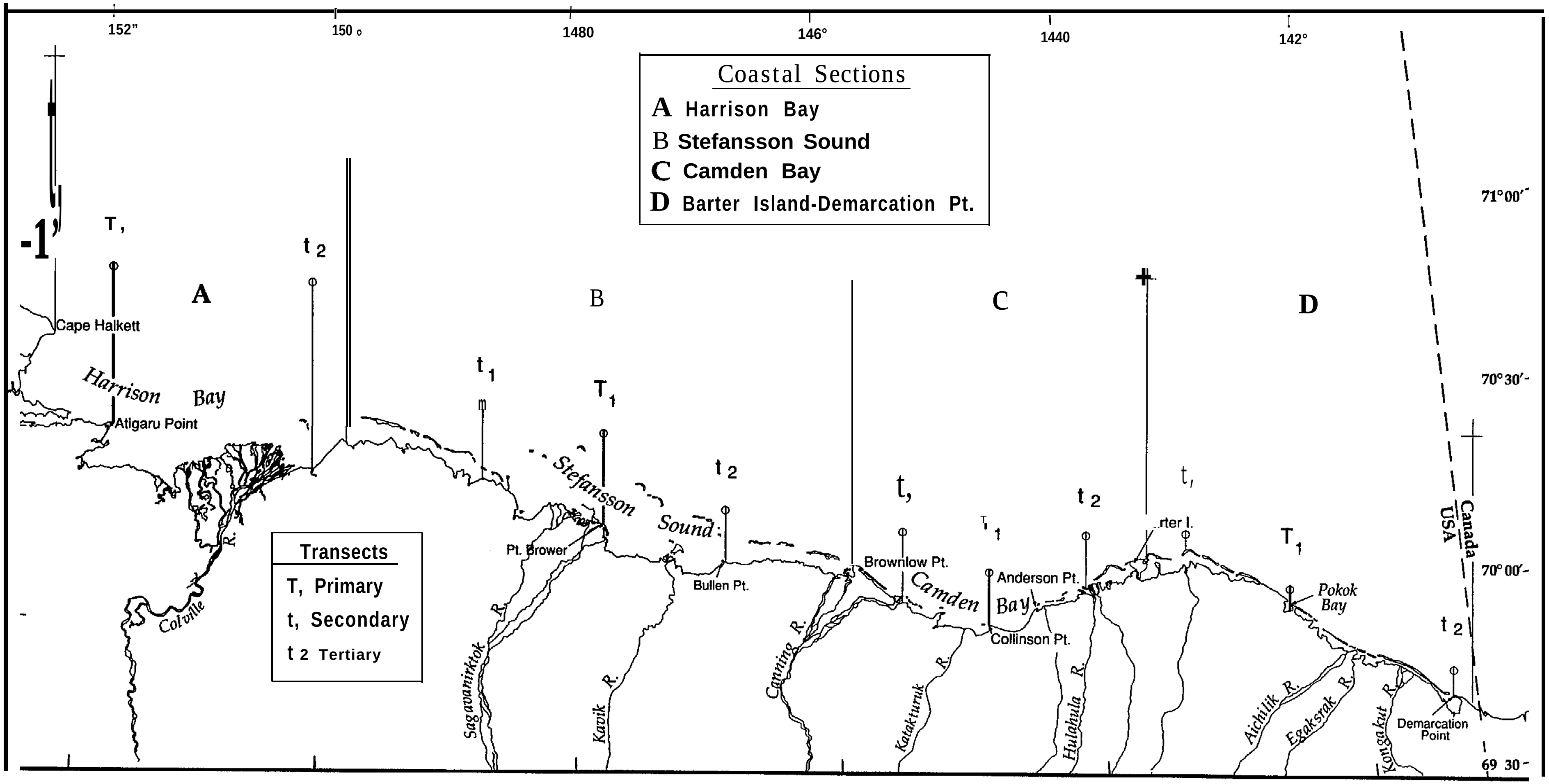

Figure 5.--Location of study area sections and sampling transects.

Sampling Strategy

Although station sampling along established transects was initially proposed it was also recognized that prevailing ice conditions might render such a plan infeasible. The planning was necessary, however, to organize our strategy as to priority of offshore areas to be sampled. Within each coastal section, primary sampling transects were identified off Atigaru Point, Point Brewer, Collinson Point, and Pokok Bay (Figure 5). Initially, offshore sampling would be conducted at selected stations beginning at an inshore station (5 m) extending perpendicular to the coast and into marine waters. If these primary sampling sites were successfully occupied, opportunistic sampling would be conducted within the coastal section to provide a broader perspective to the offshore effort.

The intent of field sampling was not only to obtain arctic char from offshore locations but to sample fish from various "habitats" defined by water property characteristics. Three 15-day cruises were tentatively scheduled for field work in 1988. Our strategy was to conduct offshore sampling in two "sections" during each cruise, with an anticipated minimum of 50 seine sets per period.

METHODS

Stock Identification Requirement

Sampling requirements for arctic char stock identification investigations were determined in consultation with the Division of Fisheries, FWS, Anchorage, Alaska. A target of 200 arctic char per sampling period was selected based on the following rationale: (1) as many as 20 populations might be represented in offshore samples, (2) a minimum of 10 individuals per population was required for GSI stock recognition, and (3) collection of larger numbers of arctic char would not be permitted by the State of Alaska.

Other arctic fish investigators were to provide additional mixed stock samples (200 fish/collection) to RU 682 from their coastal sampling sites (Everett and Wilmot, in prep.): FWS--three collections from Kaktovik; North Slope Borough--two collections from Harrison Bay; LGL Research Associates--two collections from the Endicott Causeway; and Canadian Department of Fisheries and Oceans--two collections from Phillips Bay In addition, Canadian scientists agreed to provide two samples of 50 fish each for GSI baseline development for the Big Fish and Rat River stocks. A total of 2,700 arctic char were to be obtained in 1988.

The NOAA stock identification objective relative to offshore sampling involved collection and delivery of preserved char tissues to the FWS in Anchorage for GSI analysis. Ideally, the entire sample would be collected at one location at a single point in time. In order to contend with expected low fish densities offshore, a protracted acquisition period (as long as 5 days) was adopted. After initial captures were made, additional sampling for arctic char would occur near the original collection site. A similar collection strategy

had been used successfidly bythe FWSin1987(Everett eta.l. 1988). Conceptually, stock identifications and intermixing could still be estimated, although some resolution in the stock predictions might be lost with respect to time and areal composition of the catch.

Precision and accuracy in GSI are related not only to sample size but also the total number of loci screened and the amount of genetic divergence observed in the populations being studied. Genetic baselines for 15 populations of arctic char had been electrophoretically determined prior to the 1988 field season (Everett et al. 1988). Simulation analysis of artificially created "mixed stocks" composed of known baselines indicated: (1) highest accuracy in the GSI occurs when the mixture is composed of an individual stock and (2) lowest accuracy occurs when many stocks contribute to the mixture.

Fish Sampling

Three survey cruises were completed by NOAA in 1988: Cruise 1, 30 July-12 August; Cruise 2, 17-28 August; and Cruise 3, 1-9 September. NOAA's 36-ft aluminum vessel "1273," which was configured as a drum seiner, and a 17-ft skiff were employed for seining. The NOAA vessel possesses several attributes that are useful for working in the Beaufort Sea: (1) it has an ice-reinforced hull; (2) it has a shallow draft (4 ft); and (3) its size is well suited for onshore-offshore transits between barrier islands and the exposed coastal sea. Active sampling methods (purse seining) were chosen in 1988 to (1) conduct offshore sampling in ice infested waters, and (2) provide samples allowing the direct relation of fish catch to known (at the time of capture) environmental conditions.

Prior to each cruise, an aircraft. reconnaissance of the study area was conducted to determine which "sections" could be fished with least hindrance from ice. Upon arrival at a fishing site, the station location was determined from Loran C or SatNav fixes. The accuracy of the positions is approximately 0.5 km. Depth was determined by fathometer. Inshore gillnetting locations were determined from SatNav fixes and by dead reckoning from navigation charts.

The primary sampling gear was a 150-m-long by 7.3-m-deep purse seine designed to sample small schooling fish in shallow waters (Martin et al. 1986). The net dimensions (stretched-mesh) were: seine body, 19 mm; and bunt, 6.3 mm. This net is well suited to the Arctic because target species tend to be relatively small, seldom exceeding 700 mm FL. Winds exceeding 10-13 m/see would prohibit seining.

The purse seine was set across the current and held open for 10 or 20 minutes in a large semicircle before closing. All sets were blind. Although use of an electronic fish finder to locate schools of fish had been planned, damage to the transducer precluded its use. When arctic char were captured additional sets were made in that vicinity to obtain as many fish as possible.

Gillnets were fished off beaches when "1273" was anchored or during periods when wind, fog, or ice prevented seining. The 46.2-m-long gillnets had panels of variable mesh

size (25, 50, 75, 100, and 150 mm), constructed of floating (monofilament) and Uroko Ultra sinking (multi-strand blend, little twist) web. Generally, three shackles of net were fished together. The shoreward end of the gillnet was anchored to the beach and the net extended perpendicularly to the coast. A sinking gillnet was usually fished closest inshore to reduce hazards to migratory waterbirds which tend to swim close and parallel to the shoreline. The gillnets were fished for variable periods, often overnight. However, where amphipod predation on netted fish was great, the nets were tended as often as every 2 hr to remove accumulated fish or debris. Frequent checking also reduced mortalities of netted fish.

At most fishing stations a small dredge was fished to provide information about species composition of the shallow water benthos. The dredge, which was fabricated in the field, also provided an index of species abundance. Dredge samples were sieved through a l-mm-mesh screen and dominant organisms were identified. A list of invertebrate species by station is presented in Appendix A.

Selected fish were subjected to a detailed taxonomic analysis involving various meristic and morphological measures and counts. The species studied include arctic char, least and arctic ciscoes, rainbow smelt, and fourhorn sculpin (see Appendix B). AU captured fish were examined for tags, tag scars, or other marks indicating previous capture or predation attempts. Tagging wounds and scars were reported as described by Fruge (1988).

A few zooplankton samples were collected with a 20-cm-diameter bongo sampler equipped with paired 120- and 333-pm-mesh nets. The sampler was towed near the surface for 10 minutes at a speed of about 0.5 m/sec. Conventional double oblique tows were not possible due to the shallow depths we were restricted to. Zooplankton samples were washed down onboard and preserved in buffered formalin. Zooplankton sampling was accompanied by Secchi disc readings to determine the depth of light penetration.

Physical Data

Thermohaline structure was recorded at each seine station with a portable conductivity-temperature-depth instrument (Applied Microsystems CTD-12) having an internal recording capability. The instrument's depth, temperature, and salinity sensors are accurate to within 0.10 m, 0.03°C, and 0.2 ppt, respectively. The CTD stores data in an internal memory and records eight samples of temperature, conductivity, and pressure per second. During oceanographic casts, the CTD instrument's sensors were held just below the sea surface and allowed to equilibrate, then the instrument was slowly lowered to within about 0.5 m of the bottom. Upon completion of the cast, CTD data were downloaded to a Zenith laptop portable computer, reviewed for accuracy, and stored on minidiskettes for processing.

Other physical measurements were taken in concert with oceanographic casts. Surface temperatures were measured with a bucket thermometer, which was held just below the sea surface and allowed to equilibrate for a few minutes before being read. Wind speed and direction also were estimated.

Satellite Imagery

Visible band and thermal satellite images were acquired from the Geophysical Institute of the University of Alaska (OCSEAP RU 716). NOAA Advanced Very High Resolution Radiometer (AVHRR) and LandSat Multi-Spectral Scanner (MSS) scenes were obtained for 13 clear days during summer 1988. The images were used for assessment of summer ice conditions and fish habitat availability. The ground spatial resolution of the AVHRR sensor is 1.1 km at nadir. The MSS instrument has a nominal ground resolution of 79 m × 79 m.

Fish Sample Processing

Seine and gillnet catches were sorted to species, counted, and individually measured. In the few instances of large reported catches, catch size was estimated using a bulk sample approach. In such instances, the total weight (rather than individual weights) was obtained and length frequency information was collected from a representative subsample of the catch. Fork length (mm) and wet weight measurements (g) were taken immediately after fish capture. For consistency, weight observations were recorded by the same individual throughout the summer.

Fish weights were measured with Chatillion IN-15 sliding scale (0.1 kg accuracy) and Salter #235 hanging dial (1 g) instruments. Concerns about the accuracy of the sliding scale instrument were addressed later in a calibration test using a NEXUS balance (0.1 g accuracy). The results identified a tendency for sliding scale weights to be heavy by an average factor of 2%. Therefore, all fish weights determined by the IN-15 were corrected to reflect this difference.

Information on sex and maturity state was collected from fish that were not sacrificed. The following classification was used:

Sex	*Spawning Condition*	*Index*
M/F	Immature	1
	Will probably spawn in 2 yrs	2
	Will probably spawn within 1 yr	3
	Will probably spawn this year	4
	Has spawned once. Eggs are immature and will not spawn for 2 yr	5
	Has spawned once. Will spawn again within 1 yr	6

Maturity state is based on an assessment of gonadosomal development (Nielsen and Johnson 1983). Size, coloration, and remnant structures provide qualitative indicators of various stages of fish maturity. In immature fish the testes and ovaries are very poorly developed and translucent. As fish mature the gonads occupy increasing portions of the ventral cavity and are opaque (M/F 2) to white (M/F 3).

Additional processing was performed on arctic char and coregonids. Samples of heart, eye, and muscle tissue were excised from all arctic char and immediately placed on dry ice. Tissue acquisition and preservation methods described by Everett (1988) were followed. In addition, some tissues of arctic ciscoes and least ciscoes were retained for use in other genetic studies planned by the FWS.

Ages of the dominant anadromous fish were estimated using established age-length keys reported in the scientific literature. The sources of all size-at-age relationships employed are documented at appropriate places in the text. Otoliths were removed from 42 arctic char, 90 arctic ciscoes, and 28 least ciscoes, stored in glycerine, and sent to the FWS for processing. The otoliths are representative of the entire size range of fish sampled. These samples are being aged and archived by the FWS as part of their developing database on Alaskan arctic fishes.

The food habits of selected arctic char were visually examined. The fish that were examined were either those being collected for GSI or those for which detailed taxonomic work was being performed. The analysis involved observations of prey species composition and stomach fullness.

Analytical Procedures

Fisheries Data

Catches (total numbers of fish) from 10- and 20-min sets were transformed $[\ln(x+1)]$ and compared for differences in catch by set time fished. No significant differences (Student's t, $P < 0.05$) were found and thus catch data were pooled for subsequent analysis. Catch per unit of effort (CPUE) is presented as catch per set for seine data. Gillnet catches have been standardized to 10-hr set periods. Fish densities estimated from the seine catches are presented as numbers of fish per 100 m^2 surface area. The density estimates assume a surface area of approximately 1,800 m^2 fished during each seine set (i.e., the area of a circle with a circumference of 150 m).

Length frequency analyses were performed to determine size and approximate age composition of species sampled. Fork length frequencies were plotted for the major species captured by total catch and gear-type employed. Because of the small numbers of fish involved, the widths of length increments depicted in frequency histograms (horizontal axis) were chosen by Statgraphics software. This presentation varies from traditional methods involved in more detailed modal analysis (Anderson and Gutreuter 1983).

Weight-length relationships were described for four anadromous species. The regression model used was:

$$\ln (W) = \ln (a) + b \ln (L) + \xi,$$

where a and b are constants, L is the fork length (mm), W the wet weight (g), and ξ the error term. Standard correlation analysis was used to describe the association between weight and length.

Condition factors (Ku) were computed for the dominant anadromous species to provide a general index of fish well-being (Anderson and Gutreuter 1983). This index is routinely calculated in Beaufort Sea fish studies (e.g., Fruge et al. 1989; LGL 1989) as an easily obtained indicator of population growth vis-à-vis ambient environmental conditions. A Kn value of 1 depicts an “average” fish. Condition factors were calculated using the method of LeCren (1951):

$$Kn = W/aL^b,$$

where W and L are as above, and a and b are the coefficients determined from regression analysis.

A chi-square (χ^2) goodness-of-fit analysis (Sokol and Rohlf 1969) was used to investigate habitat utilization by fish. The χ^2 analysis is often used to relate animal occurrence to habitat-type in exploratory research (Green 1979) and is commonly employed (e.g., Brown and Winn 1988). The null hypothesis tested is that fish frequency of occurrence does not differ significantly between habitats. If an organism spends proportionately more or less time in a habitat than expected the inference would be that it is preferred or avoided. Habitat-types were hydrographically defined. In a practical (large-scale) sense, three types (brackish, transitional, and marine) can be delineated in the coastal Beaufort Sea. Porter and Church (1987) note that the impact of areal boundaries on inferential analysis is unimportant in regularly distributed (vs. aggregated pattern) habitat-types.

Prior to the field season we anticipated seining at 150 stations. Assuming that the fishing would be quite evenly distributed in three habitat-types, the power of the χ^2 statistic (P = 0.05, 2 df) would be about 90% (Cohen 1977). The sample size would be large enough to detect a significant difference in 90% of the cases. With this power a Type II error (beta) would be expected about 10% of the time. A testing power of 80% is commonly used in inferential analysis, and, in this instance, would require sampling at 100 or more stations.

Physical Data

CTD data were quality controlled and processed by conventional methods. Sensor readings were converted to engineering units and pressure sorted into 0.1-m bins. Data in each bin were then averaged to derive the temperature and conductivity for that pressure. Empty bins were filled by a value derived from interpolating between closest non-empty bins. Salinity and density were calculated and stored along with temperature as a function of depth. Data recorded during the lowering of the instrument were primarily used for analyses in order to minimize turbulence-induced effects on the sensors due to passage of the instrument through the water. Plots of temperature, salinity, and density (sigma-t) versus depth and plots of temperature vs. salinity were examined to detect erroneous data and to categorize stations in terms of thermohaline structure and properties (see Appendix C). Due to the frequency of suspected erroneous readings at the sea surface, l-meter data are used in the following discussions to represent conditions at the sea surface.

RESULTS

Genetic Stock Identification

A total of 1,209 arctic char were obtained as the result of collaborative sampling efforts in 1988. Samples were collected as follows (in total numbers of fish *per* indicated coastal site): 615, Endicott Causeway; 91, Mikkelsen Bay; 378, Kaktovik; and 127, Phillips Bay. The Mikkelsen Bay sample was provided by NOAA. Preliminary analysis suggests that the Mikkelsen Bay char represented a mixed aggregate of stocks from the Ivakshek (40%), Babbage (23%), Firth (16%), Egaksrak (11%), Hulahula (6%), and Lupine/Ribdon (3%) rivers (Everett and Wilmot, in prep.). Although confidence levels are not presented here, the authors feel that the GSI reasonably accounts for 79% of the stock mixture.

Physical Oceanography

A total of 45 CTD casts were obtained in the coastal region between Thetis and Barter islands (Figure 6) in conjunction with purse seining. Cast depths ranged from 2 to 13 m. Coastal water (temperature = >2°C, salinity = <17.5 ppt, sigma-t = <14), marine water (temperature = <1°C, salinity = >28 but <32 ppt, sigma-t = >23), and transitional waters (temperature = -1 to 2°C, salinity = 17.5-28 ppt, sigma-t = 14-23) were observed (Figures 7 and 8). Temperatures at 1 m ranged from about –1.0°C to 6.6°C, while salinities were between 0.8 and 28.7 ppt. However, most observations from the l-m depth were in the temperature and salinity ranges of 2–7°C and 10-15 ppt, respectively, and thus were classified as coastal water. Coastal water prevailed throughout the water column at many stations inside the barrier islands (e.g., in Stefansson Sound), which were relatively shallow.

With few exceptions (discussed below), marine waters commonly occurred at depths greater than 6 m. Marine waters were observed only at stations in the Camden Bay area. Due to the presence of sea ice, no CTD casts were made far enough offshore to reach purely marine waters.

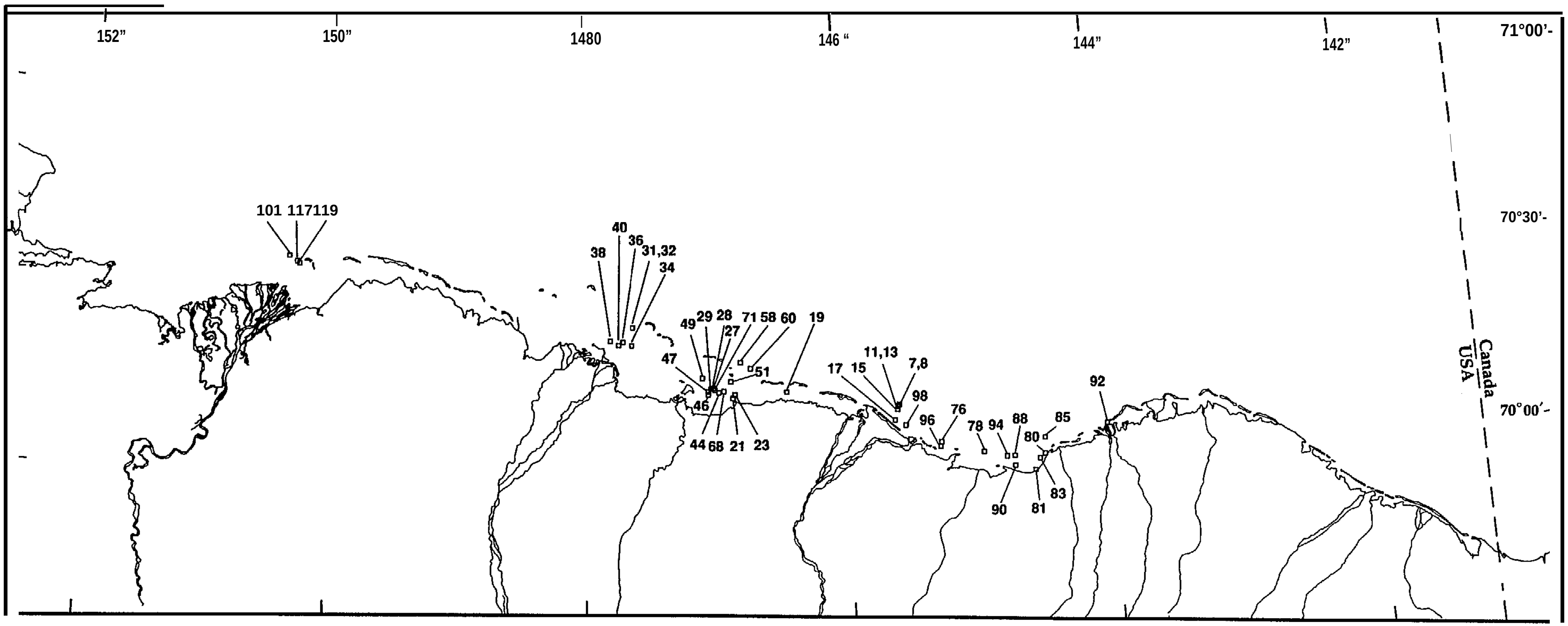

Figure 6.--Location of offshore **hydrographic** profiling stations (CTD casts) in 1988.

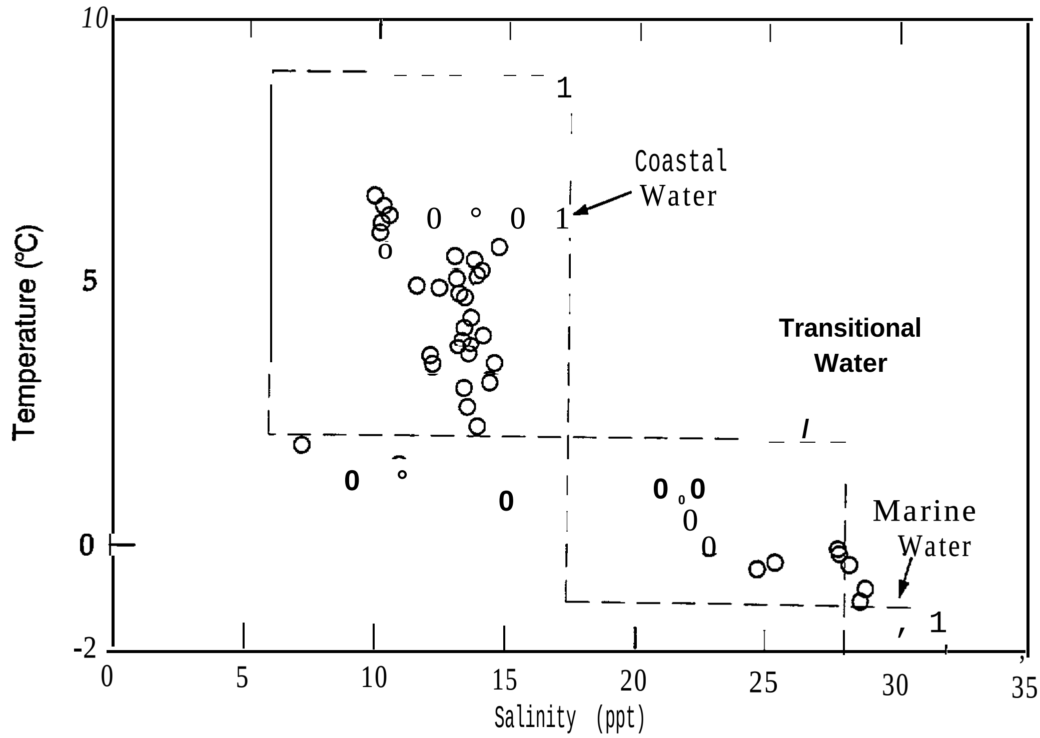

Figure 7.--One-meter temperature-salinity values, **all** stations combined.

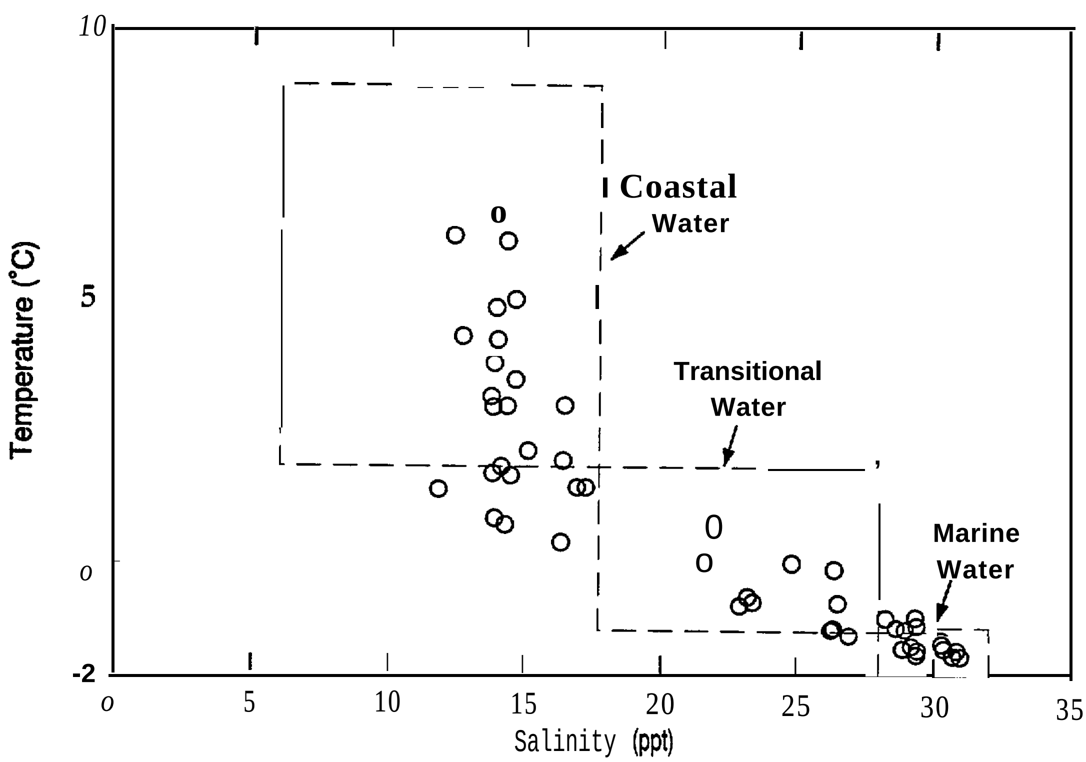

Figure 8.--Bottom temperature-salinity values, all stations combined.

Transitional waters formed by the mixture of coastal and marine waters were present at many stations. At deeper stations occupied in Camden Bay during the early part of the open-water season, transitional water frequently coincided with a pronounced **pycnocline** separating the coastal and marine water masses (Figure 9). In the latter part of the open-water season, transitional-type waters were prevalent throughout the water column at widely scattered stations. That **thermohaline** structure can be attributed to a combination of seasonal cooling, decreased freshwater input, and wind mixing.

Local changes **of water properties were evident in areas** where stations were occupied on several occasions. In **Mikkelsen** Bay seven CTD casts made in a 5.5-km area **during** the period 4-12 August illustrate relatively short-term fluctuations (Figure 10). The first cast **(B04026)** appears to reflect conditions immediately after a strong wind event, as temperature and salinity were essentially invariant throughout the water column. Casts **B03041,** B03043, and B03045 represent conditions 5 days later. Note the warmer surface temperatures and thermal **stratification.** Salinity, however, remained little changed **from** the previous observation. In isolation, the observations are suggestive of in situ warming due to insolation. However, a storm event with a westerly wind component exceeding 10 **m/sec** occurred on 7 August (Hale 1989). Such an event would be expected to vigorously mix the entire water column in **Mikkelsen** Bay. Perhaps the altered **thermohaline** structure resulted from advection of the **Sagavanirktok** River plume to the area by easterly-flowing, wind-driven currents. Large changes in both temperature and salinity structures are evident in casts B03067, B03070, and B03072, made on 11-12 August. While temperatures at 1 m remained much the same as during the prior observations, near-bottom temperatures were markedly lower than those previously observed. Similarly, l-m salinities were little changed, while **near-bottom** salinities were considerably higher than previously. Pronounced **thermoclines** and **haloclines** were present between 2 and 3 m. Evidently, the near-bottom water had been displaced by transitional waters sometime between 9 and 11 August. Wind records from a meteorological station at Camden Bay showed a prevalence of moderate winds with about a 5 m/see" easterly component during that period (Hale 1989). Offshore movement of surface waters and compensatory onshore movements of sub-solace waters would be expected under such conditions, thus promoting stratification.

The seasonal evolution of regional thermohaline structure is reflected in CTD data from Camden Bay. During early August (casts CO1OO6-O14), a pronounced two-layer stratification was prevalent in the bay *(Figure* 9). A 5-m-thick surface layer composed of coastal water having temperatures and salinities of 5-6°C and 10-11 ppt, respectively, overlay marine water having temperatures and salinities of less than **–1.0°C** and greater than 28 ppt, respectively. The **pycnocline** occupied the 5-9-m depth zone. In late August (C04087, **C04089, C04093) thermohaline** stratification was very weak. Near-surface temperatures and salinities were **0–1°C** and 23-28 ppt, respectively. Near-bottom temperatures were -1 to O"C, while salinities were 25-28 ppt. Thus during the 3 weeks between the initial and second samplings, the nearshore waters in Camden Bay had changed from the early open-water season **thermohaline** structure to the more marine-like structure that typifies coastal waters in the latter portion of the open-water season.

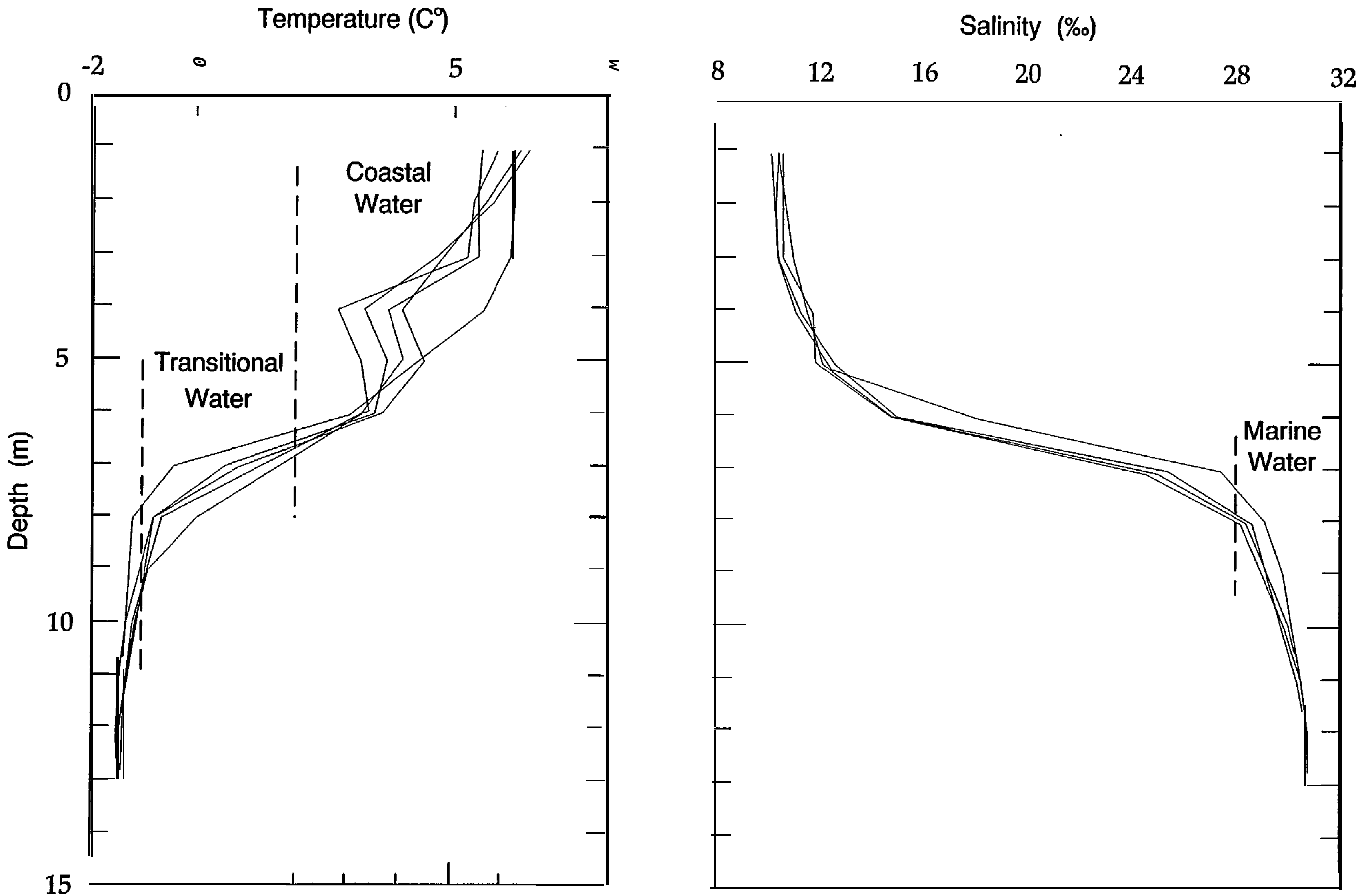

Figure 9.--Temperature and salinity profiles, western Camden Bay, 2-3 August 1988.

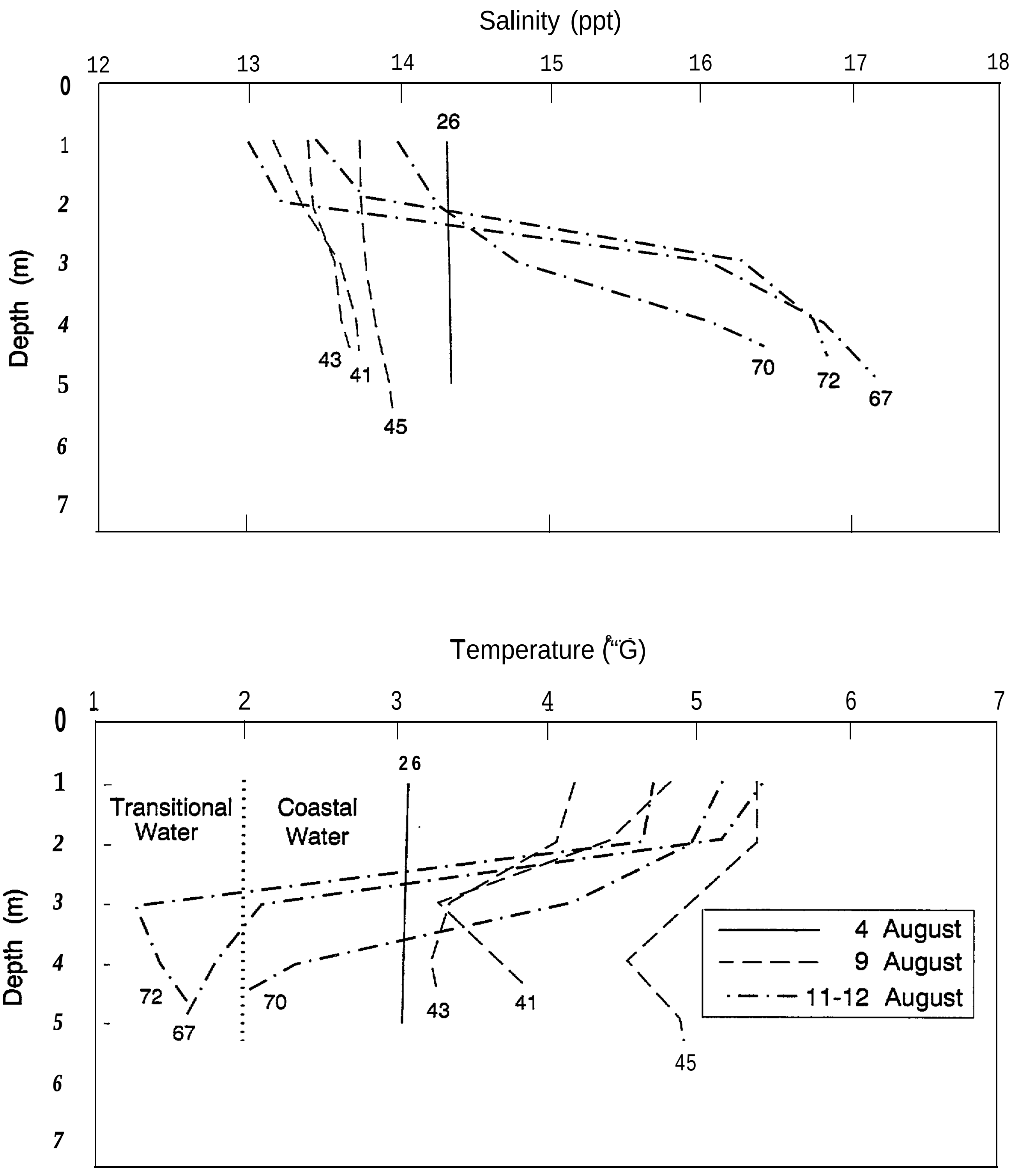

Figure 10.--Salinity and temperature profiles, Mikkelsen Bay (profiles identified by last two digits of cast number).

Local, as well as regional-scale, processes also may have been influential in producing the late August thermohaline structure. Sustained winds with a moderately strong easterly component occurred during the 3-day period just prior to these casts. The bathymetry and configuration of the eastern end of Camden Bay appear conducive to inshore upwelling during easterly winds, which might explain the cold, saline water observed there in late August. Thermohaline properties at the sea surface (temperature = -0.97°C, salinity = 28.63 ppt) approached those of marine waters just off the beach in eastern Camden Bay (C04082).

Four CTD casts were made in juxtaposition to each other west of Thetis Island between 27 August and 3 September. Because of the proximity of this area to the Colville River, one would expect the local water characteristics to be strongly influenced by river outflow. This would be especially noticeable during periods of peak river discharge in early summer. Observed late summer, short-term fluctuations of salinity structure in this area were considerable. Surface waters were quite cold, reflecting the onset of seasonal cooling. One-meter temperatures ranged between l°C and 1.25°C. In contrast, l-m salinities fluctuated markedly. They decreased from 21-23 ppt to 1-9 ppt during the observational period. Near-bottom temperatures at all stations were between - 1°C and 0°C, while salinities decreased from 28 ppt to 23 ppt over the same interval. The temperature-salinity data suggested the presence of transitional water overlying marine water on 27 August. The marine intrusion was not evident during the subsequent sampling, when the entire water column was occupied by fresher waters. Also worth noting is the fact that our operational definitions of water masses were becoming less useful with the onset of autumn and associated rapid cooling of surface water. A few weeks earlier the low-salinity waters observed near Thetis Island almost certainly would have been classified as coastal waters.

Catch Summary

Purse Seine

During 1988, pack ice was seldom more than 4 to 5 km offshore of the coastal barrier islands. East of Barter Island, prevailing winds kept the ice close to the mainland throughout July and August. This prevented access to several of our proposed sampling areas. The nearshore presence of the pack ice also confined raft ice to a narrow corridor between the beach and the pack throughout the summer. In Camden Bay this corridor was only 10-13 km wide during periods of greatest open water availability. The raft ice moved on- and offshore throughout the summer in response to local winds and often impeded our movements and fishing efforts.

Most seining occurred in three general areas: eastern Stefansson Sound (outer Mikkelsen Bay), in Camden Bay, and near the Colville Delta (Figure 11, Appendix D). Other sites were located near the Endicott Causeway and offshore of Barter Island.

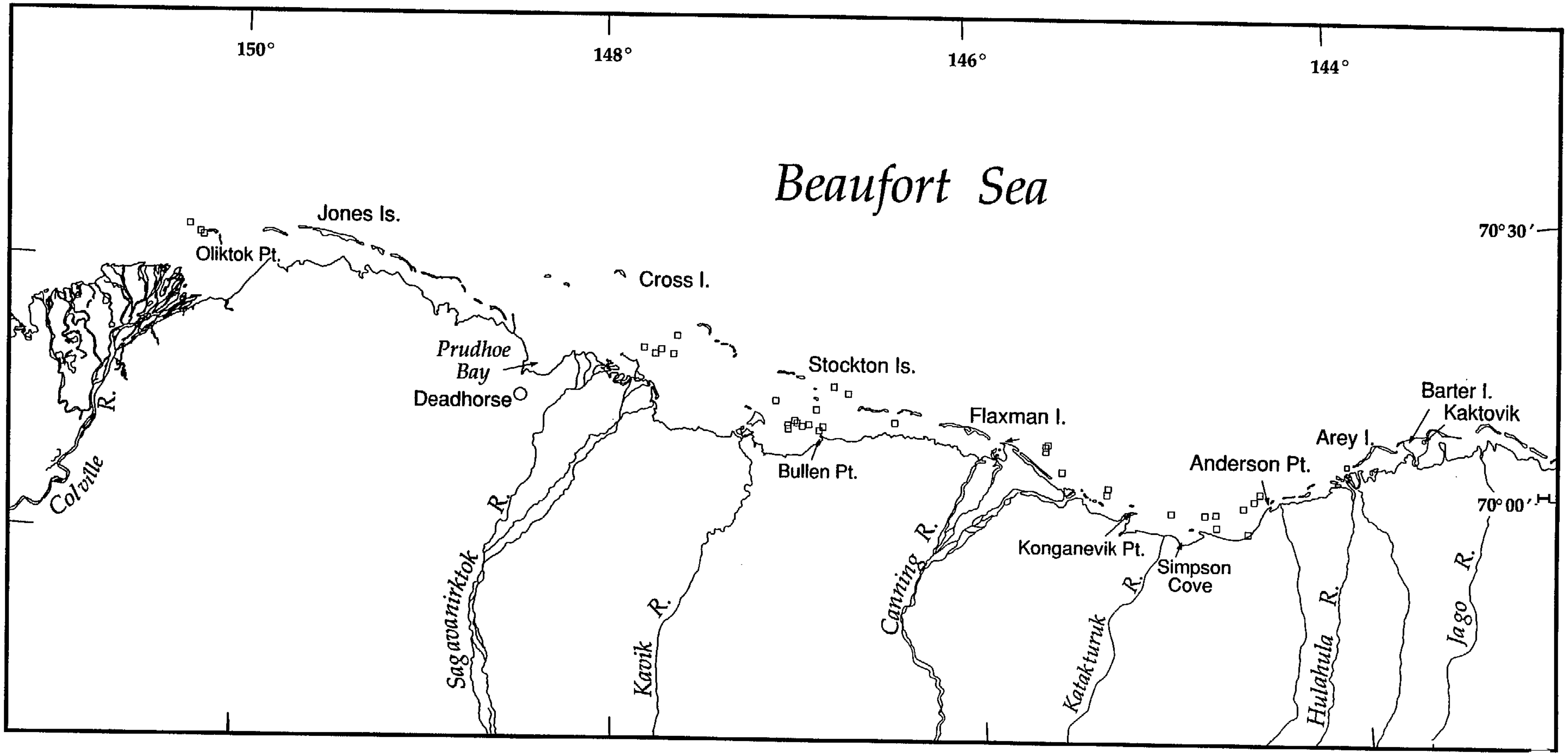

Figure 11.--Purse seine station locations in 1988 □ designates station location).

A total of 42 seine sets were successfully completed; 17 of these were water hauls (catch = O). Numerous other set attempts were aborted during the summer due to high winds, ice, or other adverse fishing conditions (e.g., fog, hanging the net). In several instances, small catches were associated with the aborted sets. These "aborted catches" have not been considered in the total identified above. They were, however, considered as "successful sets" by Thorsteinson et al. (1989) for preliminary evaluations of habitat use in an analysis employing presence/absence data.

The distribution of the 42 completed sets included 28 sets during Cruise 1, 12 during Cruise 2, and only 2 sets during Cruise 3. The observed trend of decreasing sampling effort with time reflects the storm and ice conditions encountered in 1988. Offshore habitats were mostly inaccessible after August 15. In September, ice coverage of 90–100% in nearshore waters restricted our sampling to inshore fishing near Oliktok Point.

A total of *3,549* fish were captured in the purse seine (Table 1). This represents an average catch rate of 84.5 fish/set. Not unexpectedly, a few sets produced the greatest catches. This is indicative of the low densities and patchy distributions of fish in offshore waters. Capelin and arctic cod were numerically predominant, comprising 74.4% and 23.5% of the total catch, respectively. Of the anadromous species taken in the seine, the arctic char was most abundant, representing 1.5% of the catch. Only three arctic ciscoes (one per cruise) were captured by the seine.

Table 1 provides a summary of selected environmental information associated with the seine catch data. Correlation analysis indicates a relatively strong association between total seine catch and sea surface temperature (r = 0.64) and more moderate associations with station depth (r = 0.48) and depth of upper layer (r = 0.43). The total seine catch was weakly associated with near-bottom temperatures (r = 0.21) and negatively correlated with the mean temperature of the upper layer (r = -0.04) and near-bottom salinities (r = -0.32). The upper layer generally consisted of coastal water lying above the pycnocline.

When anadromous fish were encountered, the average conditions of pelagic habitats were relatively warm (3–5°C) and of intermediate salinities (14-24 ppt). Not unexpectedly, marine species (e.g., capelin and arctic cod) were found in greatest numbers at stations possessing cooler temperatures and higher salinities than their anadromous counterparts prefer.

Although we were unable to affix a depth of capture to seine-caught fish it is likely that the arctic char and arctic ciscoes were present in the upper layer. A vertical positioning of anadromous fish in the upper water column is supported by several pieces of circumstantial evidence. First, the largest catches of anadromous fish in surface-bottom gillnet fishing in Camden Bay have typically been reported from the upper 2.4 m (Fruge et al. 1989). Second, coastal waters are extremely turbid and visibility conditions beneath 2 m can be expected to be poor. In 1988 we found an average depth of light penetration to be 2.31 m (range = 0.5-3.99 m, n = 6) at several offshore stations (depth range =

Table I.--Active capture and environmental summary, 1988 (42 sets; 3,549 fish captured).

	Arctic char	Arctic cisco	Rainbow smelt	Snailfish	Ninespine sticklebacks	Pacific sandlance	Capelin	Sculpin[1]	Arctic cod
GENERAL									
Total number of sets with fish	2	3	1	6	1	1	6	4	21
Total number of fish captured	52	3	1	10	1	3	2,640	4	835
% occurrence in catch	1,5	t[2]	t	t	t	t	74.4	t	23.5
CPUE (catch/set)	1.18	0.07	0.02	0.23	0.02	0.07	60	0.09	18.98
ENVIRONMENTAL									
Depth (m)									
Mean station depth	5	4.75	—	4.5	—	5.17	5.71	5.2	6.42
Range of depths sampled	5	4.5-5.0	·	4.0-5.0	—	—	4.58-8.0	4.5-6.0	4.0-13.0
Mean upper layer	5	—	—	3.8	—	—	4.17	5	5.37
Temperature (°C)									
Mean sea surface temperature (SST)	4.35	3.95		4.5	—	—	2.76	5.3	4.78
Range of SSTS measured	3.1-5.6	3.1-4.8	—	3.0-5.6	—	—	-0.2-5.6	4,5-6.7	1.0-10.2
Mean temperature of upper layer	3.35	3.95		3.5	—	—	2.08	3.57	3.55
Temperature range of upper layer	3.1-3.6	3.1-4.8	—	0.9-5.9	—	—	-0.3-3.6	2.6-4.1	-0.3-3.6
Mean sea bottom temperature	2.35	1.1	—	1.64	—	—	0.3	1.77	1.64
Sea bottom temperature range	1.6-3.1	-0.9-3.1	—	0.5-6.1	—	—	-0.7-1.6	0,9-3.3	-1.4-6.5
Salinity (ppt)									
Mean salinity of upper layer	14.4	19.2	—	8.72	—	—	14.82	12.43	14.17
Salinity range of upper layer	14.2-14.6	14.2-24.2	—	0.6-14.6	—	—	5.2-25.7	12.0-13.3	0.6-28.0
Mean sea bottom salinity	15.75	21.6	·	13.4	—	—	22.47	14.1	17.68
Sea bottom salinity range	14.3-17.32	14.3-28.9	—	0.5-23.2	—	—	17.2-29.2	13.7-14.3	0.5-30.8

[1] Sculpin includes fourhorn sculpin, arctic hookear sculpin, and arctic staghorn sculpin.
[2] trace, c 1%.

5.5-11.6 m). Prey visibility can be expected to be a major determinant of successful predation for visual feeders. Finally, the existing information on environmental preferences of anadromous fish suggests they favor coastal brackish conditions (Craig 1989a).

The three cruises provide a temporal framework (early, middle, late) for making seasonal comparisons of the relative abundances of dominant fish species (Tables 2-4). In addition to the pelagic species sampled, several demersal species, such as sculpins, were regularly captured when the seine dragged bottom. Early in the season, arctic cod were the most abundant (mean 17.0 fish/set) and most frequently captured species in exposed coastal waters (e.g., in Camden Bay, seaward of the Endicott Causeway, and off Barter Island). For example, densities of more that 17 cod/100 m^2 were observed on 5 August (B02038) near Pt. Brewer. The hydrographic profile accompanying this set (B02037) indicated surface-to-bottom temperatures of 5.8°C to <1°C and salinities of 4 to 15 ppt over this depth range. The stratified conditions indicate the mixing of marine and brackish waters and the influence of Sagavanirktok River waters. A freshening of surface layers would be expected under the westerly wind conditions experienced on this date.

Fifty-two arctic char were captured in the offshore seining of Cruise 1. On the afternoon of 11 August, 48 fish (2.67 fish/100 m^2) were captured in a set in outer Mikkelsen Bay (B03069). This station (5.5-m) was located approximately 5 km due north of the nearest shoreline. Temperature and salinity data (B03067) indicated stratification (2-layer) with a thermocline located at 2 m. The surface temperature was 5.42°C and the bottom temperature was 1.61°C. Salinities were of intermediate character, being 13 ppt near the surface and >17 ppt at depth. Because the seine fished in both coastal and transitional waters, it is not possible to unequivocally associate the arctic char with a particular suite of habitat attributes.

Strong winds prevented offshore sampling during most of Cruise 2. During the early portion of the survey period (18-22 August); seining was attempted in Camden Bay. This was a period of marine intrusion into the bay and the catch was dominated by juvenile capelin (density = >10 fish/100 m^2), jelly-fish (unknown spp.), and to a far lesser extent, arctic cod. The catches were reported from cold waters (–0.4°C to –1.9°C) from depths of 8-10 m (e.g., C03091 and C03092). Winds were steady from the southwest at 2.5-5 m/sec. On 25 August the vessel moved to Thetis Island in search of open water in the western portion of the study area. Strong winds (>10 m/sec) and poor visibility (fog) resulted in the conduct of one successful set (with no fish) in 4 days.

Poor weather and heavy ice conditions stymied offshore sampling throughout Cruise 3 (l-9 September). Ice coverage in nearshore waters outside of the barrier islands varied from 80 to 100%. Only two seine sets were possible and both occurred on 3 September. Both sets were made at midday at stations (A03117 and A03119) located near the ice front west of Thetis Island. Station depths *were 5.0* and 5.5 m, respectively. While the two stations were located only 1.25 km apart the oceanographic conditions at each were markedly different. Temperature data from satellite images obtained on 3 September reflect widespread influence of the Colville River in the area where sampling occurred.

Table 2.--Purse seine catch summary for Cruise 1.[1]

Species	# sets with fish	Catch′				Density[9]		
		Σ	Mean	SD	Range	Mean	SD	Range
Capelin	2	2	0.07	0.26	0-1	0.004	0.016	0-0.06
Arctic cod	15	477	17.04	58.36	0-307	0.946	3.243	0-17.06
Arctic char	2	52	1.86	9.08	0-48	0.103 ′	0.505	0-2.67
Snailfish	3	7	0.25	0.85	0-4	0.014	0.047	0-0.39
Sculpins	4	4	0.14	0.36	0-1	0.009	0.021	0-0.21
Arctic **cisco**	1	1	0.04	0.19	0-1	0.002	0.011	0-0.06
All	16	543	19.4	60.58	0-312	1.072	3.332	0-17.14

[1] 28 sets including 12 water hauls.
[2]Σ = total numbers caught; mean = average catch/set; range in fish/set.
′Mean = average number of fish/100 m′; range in fish/100 m′.

Table 3.--Purse seine catch summary for Cruise 2.[1]

Species	# sets with fish	Catch*				Density[S]		
		Σ	Mean	SD	Range	Mean	SD	Range
Capelin	2	722	60.20	193.20	0-672	3.34	10.72	0-37.3
Arctic cod	4	4	0.33	0.49	0-1	0.02	0.03	0-0.06
Arctic **cisco**	1	1	0.08	0.29	0-1	0.005	0.017	0-0.06
Snailfish	1	1	0.08	0.29	0-1	0.005	0.017	0-0.06
Ninespine sticklebacks	1	1	0.08	0.29	0-1	0.005	0.017	0-0.06
All	6	729	60.75	193.02	0-672	3.38	10.71	0-37.3

[1] 12 sets including 5 water hauls.
[2]Σ = total numbers caught; mean = average catch/set; range in fish/set.
[9]Mean = average number of fish/100 m^2; range in fish/100 m^2.

Table 4.--Purse seine catch summary for Cruise 3.[1]

Species	# sets with fish	Catch[2]				Density[3]		
		Σ	Mean	SD	Range	Mean	SD	Range
Capelin	2	1,916	958.0	1,142.7	150-1,766	53.2	63.5	8.3-98.1
Arctic cod	2	354	177.0	244.7	4-350	9.8	13.6	0.2-19.4
Snailfish	2	2	1.0	0	1	0.06	0	0.6
Arctic cisco	1	1	0.5	0.7	0-1	0.03	0.04	0-0.06
Sand lance	1	3	1.5	2.1	0-3	0.08	0.12	0-0.17
Rainbow smelt	1	1	1.0	0.7	0-1	0.03	0.04	0-0.06
All	2	2,277	1,113.5	1,355.5	155-1,916	61,9	69.2	8.6-106.4

[1] Total of 2 sets.
[2] Σ = total numbers caught; mean = average catch/set; range in fish/set.
[3] Mean = average number of fish/100 m^2; range in fish/100 m^2.

At station A03117 the fishing was conducted in a relatively ice-free area adjacent to the pack. The water column was stratified (2 layers), with an upper mixed layer 2 m thick. The water in the upper layer was cold (1.07°C) and very fresh (0.77 ppt). At depth the water was –0.42°C and relatively saline (23.16 ppt). In contrast, at station A03119 the seine was fished in an area bounded on three sides by ice. The water column was mixed, with temperatures ranging from 1.27 to –0.49°C (surface to bottom) and salinities from 9.15 to 23.18 ppt. Juvenile capelin (c1OO mm) were abundant at both stations, with mean densities of >60 fish/100 m^2. While the fish densities reported at A03117 and A03119 were the highest we observed in 1988 there was an order of magnitude difference in the apparent abundance between them (i.e., 8 vs. 98 fish/100 m^2, respectively).

The seine catch at A03119 provided a "snapshot" of arctic fish interactions along the outer Colville Delta in early fall. Capelin, arctic cod, Pacific sandlance, and arctic ciscoes were feeding on an apparent swarm of mysids. Rainbow smelt were also present and may have been feeding on mysids or the smaller fish. Haldorson and Craig (1984) reported that rainbow smelt were one of the most abundant fish species in the Colville Delta in fall and winter months. Although the autumnal abundance of this species has been attributed to reproductive and wintering requirements, the actual timing of the onshore population movement may be more precisely linked to migrational or other life history patterns of capelin and arctic cod.

Satellite Data

Thermal imagery from satellite observations indicates offshore surface waters to be of heterogeneous composition, with a predictable trend of warmest waters next to the coast and coldest waters nearest the ice pack. Satellite scenes from the afternoon of 11 August indicate a patchwork of warmer surface temperatures throughout eastern Stefansson Sound. The satellite images suggest warmest SSTs (>5.0°C) in the general offshore area where 48 char were captured in one set. Coastal conditions in Camden Bay on the afternoon of 14 August, prior to the marine intrusion later that month, suggest very high SSTs (>7°C) widely distributed across the bay. Satellite photos show that ice was relatively far offshore on this date and thus may have had a reduced effect on surface temperature conditions. The influence of Colville river water on coastal habitats in Simpson Lagoon and Harrison Bay is indicated in thermal images from 3 September. In these pictures the surface boundaries between warm (0.6°C) and cold (-0.9 and –1.4°C) waters are quite distinct, with warmer waters banded near the coast.

Gillnetting

A total of 389 fish were captured by gillnetting. Gillnets were fished most extensively at Bullen and Oliktok points in 1988 (Figure 12, Table 5). At each location gillnetting was resorted to only when it became clear that seining alone would not provide the sample size needed for GSI analysis of arctic char. Although set times varied by date and area, an average set time (all locations) was 5 hr. Sampling at Thetis Island was

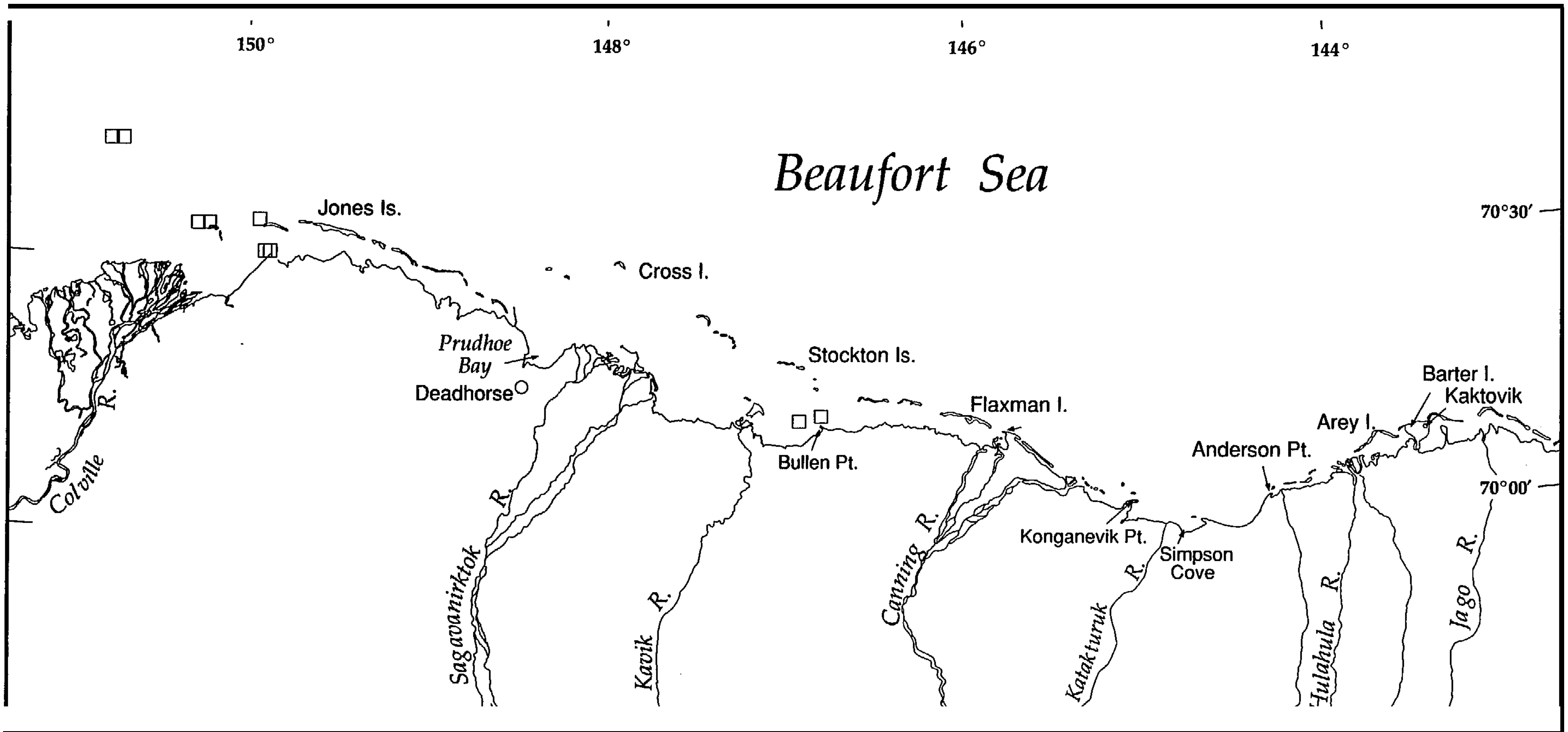

Figure 12.--Gillnet fishing locations in Stefansson Sound (□ designates net location).

Table 5.--Summary of 1988 gillnet catch?

Species	Bullen Point (9-11 August)			Thetis Island (26-28 August)			Oliktok Point (1-6 September)		
	Σ	CPUE[2]	% species composition	Σ	CPUE	% species composition	Σ	CPUE	% species composition
Arctic char	37	6.27	16.7	—		—	2	0.16	1.2
Arctic cisco	123	20.85	55.7	1	0.30	25.0	78	6.23	47.6
Least cisco	56	9.49	25.3	—		—	35	2.79	21.3
Broad whitefish	3	0.51	1.4	—		—	6	0.48	3.7
Rainbow smelt	—	—	—	—		—	8	0.64	4.9
Fourhorn sculpin	2	0.34	0.9	2	0.60	50.0	17	1.36	10.4
Arctic cod	—	—	—	1	0.30	25.0	4	0.32	2.4
Unknown whitefish	—	—	—	—		—	14	1.12	8.5
All	221	37.5		4	1.20	—	164	13.09	—

[1] Total effort: 59 hr at Bullen Point, 33.5 hr at Thetis Island, 125.25 hr at Oliktok Point.
[2] CPUE expressed as number of fish/10-hr set.

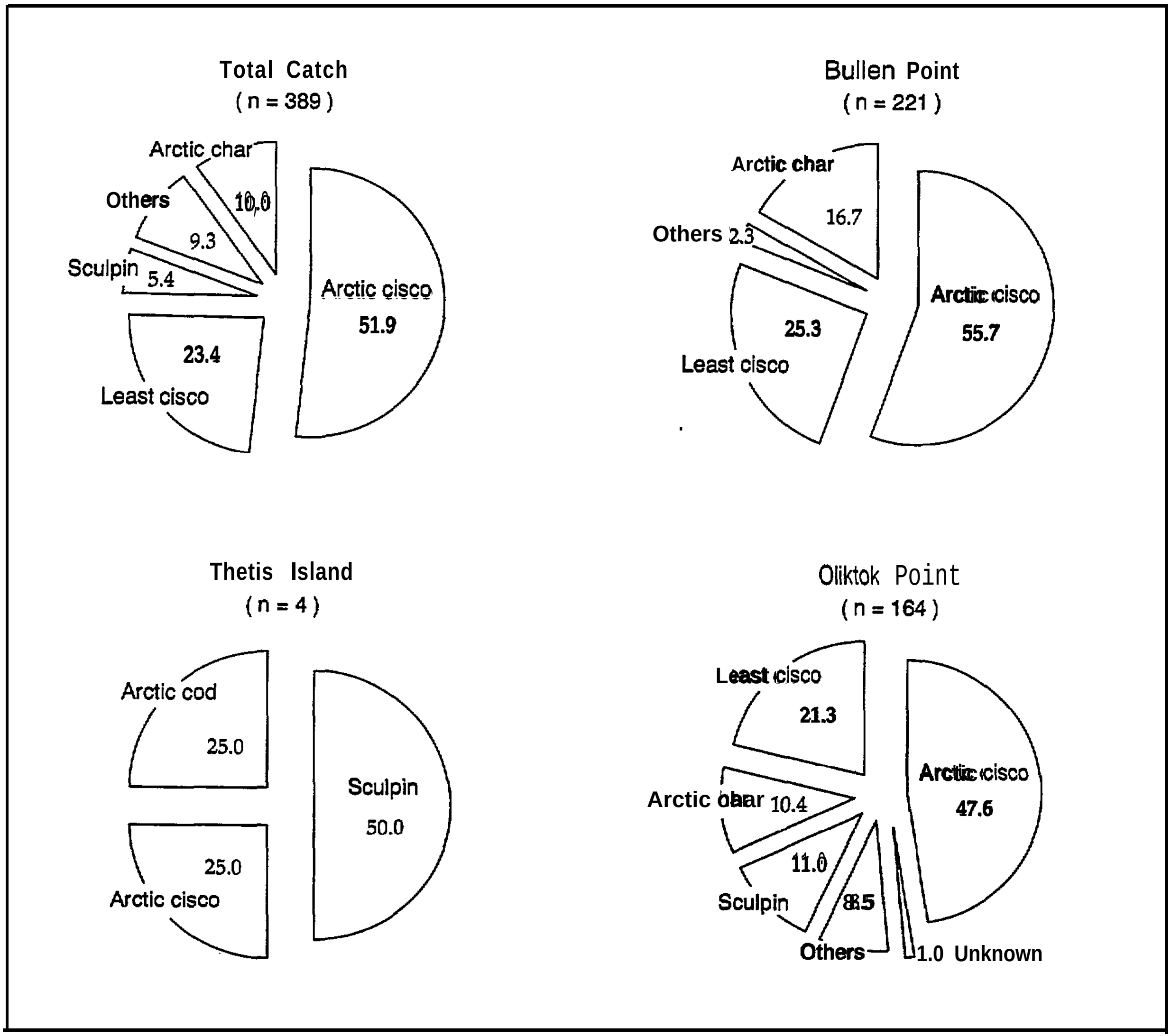

Figure 13.--Percent species composition of **gillnet** catches total catch, **Bullen** Point, Thetie Island, and **Oliktok** Point.

conducted during several "weather" days in late August when wind, fog, and ice conditions prevented safe vessel operation. Arctic char and least and arctic **ciscoes** were the most abundant species at **Bullen** and **Oliktok** points (Figure 13). Only one arctic **cisco** was captured in over 33 hr of gillnetting at Thetis Island.

Arctic char were quite abundant at **Bullen** Point in early August 1988 **(CPUE** = 6.27). Thirty-seven char were captured between August 9 and 11. These were included with the fish taken farther **offshore** by seine as part of the **Mikkelsen** Bay GSI sample. Only two fish were captured at **Oliktok** Point after September **1 (CPUE** = 0.16). The major pulse of arctic char had apparently moved into the **Colville** River during the latter part of August (LGL 1989). The **CPUE** values shown in Table 5 reflect **an** approximate three-fold greater relative abundance of fish in early August than 1 month later.

Temperature conditions were probably most responsible for the observed differences in relative fish abundance. Sea surface temperatures at gillnet sites were measured at the beginning and end of each set. In August, the nets were fished for widely varying periods (6.75-17.7 hr). During the first half of August, sea surface temperatures at fishing sites varied between 4.0 and 6.6°C. In September, nets fished at Oliktok Pt. were checked more frequently, usually at 2- and 4-hr intervals. Between 1 and 6 September, daily variations in surface temperatures ranging from -0.5°C at 0700, to a high of 1.5°C at 1300, to 0.7°C at 2000 were observed. After 1 September, easterly winds produced a continually dropping sea level along the western side of the point. This also may have influenced inshore use. Fish were captured on both sides of the net and it was therefore difficult to assess direction of movement.

Inshore changes in temperature and salinity structure due to wind-induced mixing may have been reflected in our catches. For example, a storm on the evening of 10 August had a westerly wind component of approximately 10 m/sec (Hale 1989). Gillnet catches rose from an average CPUE of 3.75 fish/hr to 7.81 fish/hr before and during the storm, respectively. Fish movements have been reported in response to a variety of storm events. Fechhelm et al. (1989) reported inshore movements of anadromous fish in delta areas during periods of marine intrusion. Others have suggested offshore movements away from the immediate coastlines during periods of strong wave action (Craig and Haldorson 1981).

Species Characterizations

Length and weight data for fish collected in 1988 are shown in Table 6. Note that only seine-caught arctic char have been separated from gillnet catches in this table. All but three arctic ciscoes and one rainbow smelt were collected at inshore stations. All of the least ciscoes and broad whitefish were taken by gillnets fished at Bullen and Oliktok points. The species composition of the gillnet catches is depicted in the pie charts in Figure 13.

Capelin, snailfish, Pacific sandlance, sticklebacks, and sculpins (other than fourhorn sculpin) were captured exclusively by the seine. The vast majority of arctic cod (>99%) were also captured in the offshore fishing. Fourhorn sculpin were captured by both gears. While never abundant, they appeared with regularity in most areas fished.

Species discussions are presented below for the anadromous fishes and dominant marine fishes sampled in 1988. All lengths are rounded to the nearest millimeter, reflecting the precision of our measurements. Emphasis was placed on the acquisition of biological data from anadromous species. Of these, the arctic char and two cisco species were most abundant in our catches. A more limited amount of data was obtained for broad whitefish and rainbow smelt. Finally, of **the several marine species that were** captured offshore, arctic cod and capelin were **numerically most abundant and are** therefore the focus of our discussions.

Table 6.--Length/weight statistics, all samples combined.

Species	Length (mm)					Weight (g)				
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Arctic char (all)	91	158	561	267.6	78.5	43	39.2	1,716.9	336.3	439.4
Arctic char (seine)	52	197	365	230.4	31.4	16	39.2	392.4	118.4	104.8
Arctic cisco (all) .	200	84	383	333.4	76.6	97	9.8	1,687.5	440.6	323.7
Least cisco	89	103	388	284.0	67.0	33	9.8	657.3	278.2	193.7
Broad whitefish	8	320	445	368.9	45.6	3	524.9	833.9	672.0	155.0
Rainbow smelt	4	133	252	219.5	57.5	3	51.0	179.5	119.3	64.6
Liparid snailfish	10	21	79	58.8	20.9	—	—	—	—	—
Ninespine sticklebacks	1	—	—	75.0	—	—	—	—	—	—
Pacific sandlance	3	75	76	75.7	0.6	—	—	—	—	—
Capelin	570	38	84	52.4	7.6	—	—	—	—	
Sculpins										
Fourhorn sculpin	22	93	245	179.6	30.7	6	39.2	147.2	78.5	53.4
Arctic hookear sculpin	1	—	—	54.0	—	—	—	—	—	—
Arctic staghorn sculpin	1	—		82.0	—	—	—	—	—	—
Arctic cod	541	22	147	75.7	20.5	—	—	—	—	—

Length Frequencies

Arctic char ranged in length (FL) from 158 to 561 mm in the combined seine and gillnet catches (Figure 14). Seine-caught arctic char ranged from 197 to 365 mm in size ($\bar{x}$ = 230.4 mm). Gillnet-caught char were larger and ranged in length from 158 to 561 mm ($\bar{x}$ = 317.5 mm). All but two fish captured with gillnets were from Bullen Point. The char gilnetted at Bullen Point (n = 37) in early August were larger (range 158-561 mm, $\bar{x}$ = 318.8 mm) than those captured at Oliktok Point (n = 2) in September (234 mm and 348 mm, $\bar{x}$ = 291 mm).

Size at Age

Fish ages were estimated from the age-length relationship for arctic char described by Fruge et al. (1989). The data used in their analysis were obtained from fish captured in coastal waters of the eastern Beaufort Sea during 1988. Judging from their analysis, most seined arctic char were age 3+. Some may have been younger, perhaps age 2+. Most fish were <240 mm FL. This small size suggests that 1988 was their first summer at sea. The *larger* seine-caught char (i.e., fish >240 mm, but <370 mm) were probably age 4+ or older (up to 7 yr). Length frequency data suggest that the gillnetted char comprise several age groups ranging from 2 to >10 yr. Considering the observed length frequency distribution and size of the sample mean, the greatest number of gillnetted char were probably immatures between 4 and 6 yr old. Fish of other ages were probably represented but in much lower numbers.

Length-Weight Relationship and Condition

The following regression model described the allometric growth relationship (Figure 15) of arctic char in our combined-gear catches:

$$\text{in } (W) = 1.04 \times 10^{-6} + 3.35 \ln (L)$$

SE (a) = 0.1823 .
SE (b} = 0.2115
r = 0.931
n = 4 1

Arctic char collected during the period 4-10 August were used to calculate a condition factor, Kn, = 1.10.

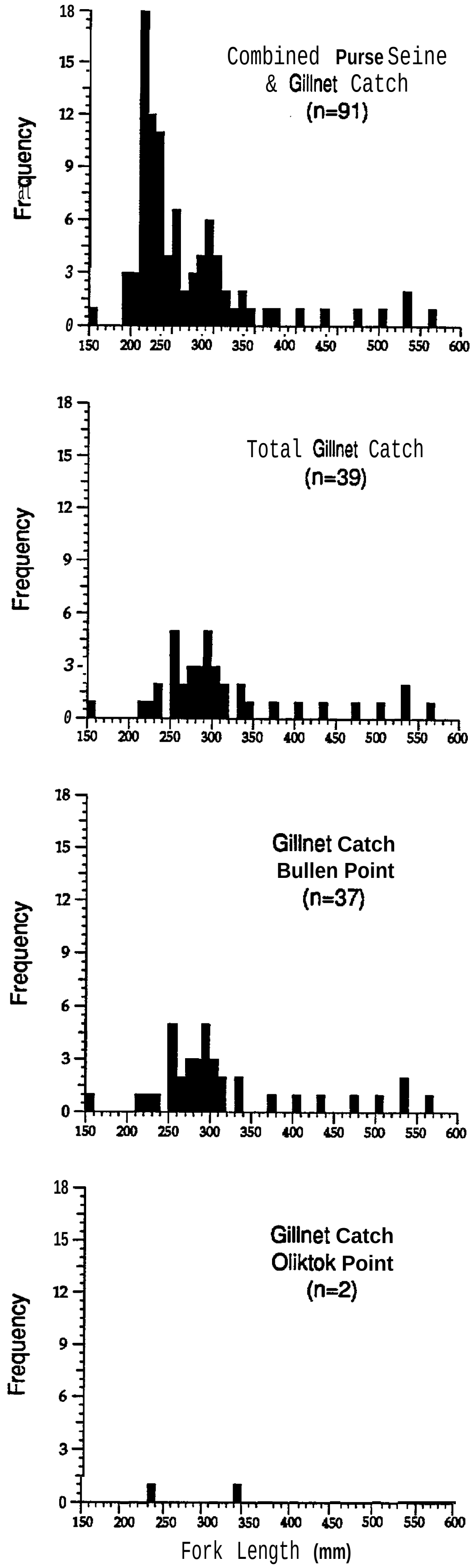

Figure 14.--Arctic char length frequencies combined gear catch, total gillnet catch, Bullen Point gillnet catch, and Oliktok Point gillnet catch.

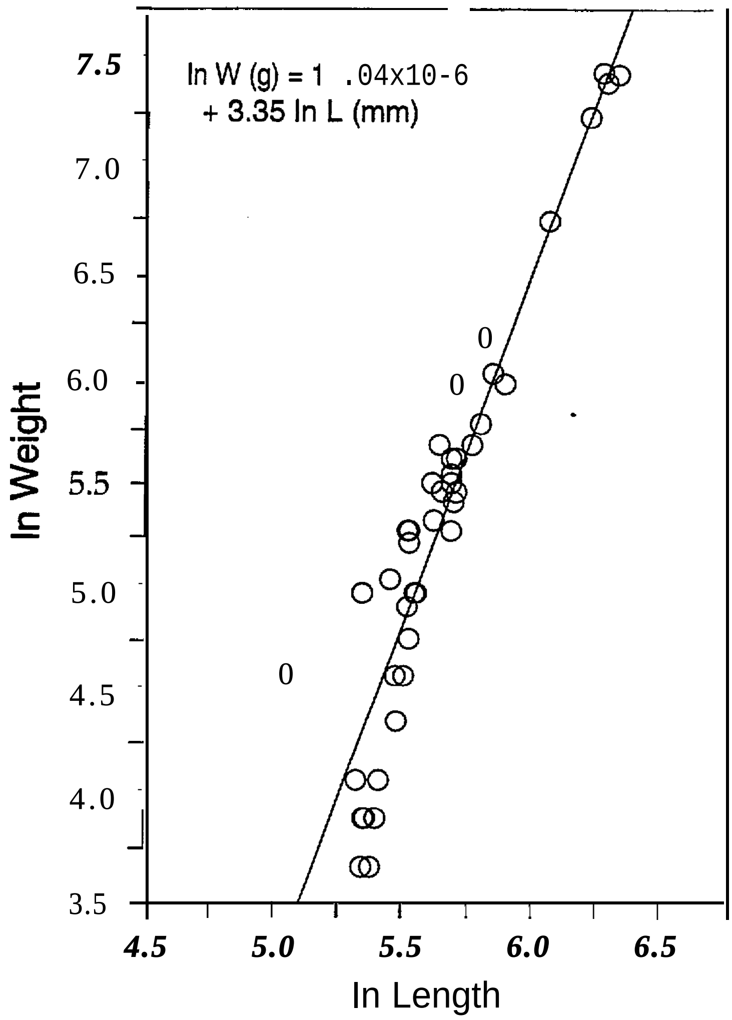

Figure 15.--Weight-length regression for arctic char.

Reproductive Status

Of 88 arctic char for which a maturity index was assigned, 84 were immature (Table 7). These fish were determined to be at least 3 yr away from first spawning. Two females (530 mm and 538 mm) were classified as F3 fish and they were probably 1 yr away from their first spawning. Only two females (401 mm and 432 mm) appeared to have spawned in the previous year (F5).

Sex Ratio

An overall sex ratio (males:females) of 1:1.6 was observed in combined gear catches. The ratio was 1:1.7 in seined char and 1:1.3 in gillnetted fish. In 1980, Craig and Griffiths (1981) reported a sex ratio of 1:1.4 for Sagavanirktok River char.

Table 7.—Length/weight statistics of three anadromous species by selected maturity state.

Maturity index	Length (mm)					Weight (g)				
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Arctic char										
M1	34	197	377	256.6	48.3	35	10	700	197.7	155.3
F1	50	158	503	247.1	51.7	24	40	1,410	222.1	279.2
F3	2	530	538	534.0	5.7	4	390	1,750	1,125.0	682.5
F5	2	401	432	416.5	21.9	—	—	—	—	—
Arctic cisco										
M1	25	111	367	240.9	80.5	21	10	700	187.1	200.2
M2	21	311	375	357.5	14.6	14	500	720	608.6	61.8
M3	4	355	379	357.8	9.5	2	550	700	625.0	106.1
M5	4	347	418	383.8	31.5	3	510	1,720	1,036.7	520.0
F1	24	120	375	231.0	59.2	23	10	600	153.5	161.6
F2	27	334	409	374.4	16.9	23	400	950	703.9	124.5
F3	5	352	391	372.5	13.6	—	—	—	—	—
F5	4	378	431	399.8	25.5	3	690	1,250	930.0	560.0
F6	3	363	379	370.7	8.0	3	560	750	650.0	95.4
Least cisco										
M2	2	220	388	304.0	118.8	—	·	—		—
M3	5	278	297	288.4	7.7	—	—	—	—	—
F2	19	233	381	308.4	44.6	9	310	670	463.3	107.2
F3	16	250	345	300.1	33.2	—	—	—	—	—

In the single seine catch of 48 char (B03064) from outer Mikkelsen Bay the sex ratio was 1:1.6. This catch was composed of an apparent school of immature char with average lengths of 220 mm in males and 224.5 mm in females. It may therefore be representative of the larger population. The data may reflect a differential rate of mortality between the sexes or that more females of this size/age class migrate to sea.

Only one other seine set resulted in the catch of arctic char. On 4 August, four larger char (one male 365 mm long, and three females averaging 306 mm) were captured off Bullen Point (B03027).

The sex ratio observed in gillnet-caught char was also variable. In an overnight set at Bullen Point (B03054) on 9 August a ratio of 1:1.5 was observed (n = 20). Two nights later at the same site (B03075) 10 char were captured and the ratio was 1:1. At B03054 the males possessed a mean length of 291.3 mm versus 339.5 mm in females. By comparison the males sampled at B03075 were longer ($\bar{x}$ = 333,6 mm) and the females shorter ($\bar{x}$ = 279.2 mm).

Food Habits

Fifteen arctic char collected in eastern Stefansson Sound during the period 4-12 August were examined for gut contents. Four char ($\bar{x}$ = 320.8 mm) taken at a 6-m depth station (B03027) were gorged on lipariid larvae, The stomachs were fully distended and larvae literally poured from their mouths at the slightest provocation. One fish had also been consuming copepods. On 11 August at another offshore (5.5-m depth) location (B03069) six char ($\bar{x}$ = 228.7 mm) had been feeding on yearling arctic cod and mysids. Closer inshore, five char ($\bar{x}$ = 348 mm) collected at gillnet stations B03062 (8/10) and B03075 (8/12) were feeding on young-of-the-year and yearling arctic cod, as well as mysids. Only one char was examined at Oliktok Point in September; it had been eating yearling arctic cod.

Arctic *Cisco*

Length Frequencies

Arctic ciscoes ranged in length from 84 mm to 383 mm (Figure 16). The average length of arctic ciscoes (both sexes and sampling gears combined) was 333.4 mm. Only three fish were captured by seining; one during each cruise. The first was captured in eastern Stefansson Sound (B03027) in early August (FL = 375 mm), the second (FL = 84 mm) at a 5.5-m deep station in Camden Bay (CO4081) on 21 August, and the third near Thetis Island (A03119) in early September (FL = 146 mm). The small size of the cisco taken in Camden Bay is indicative of a young-of-the-year fish.

In early August 122 arctic ciscoes were captured by gillnetting at Bullen Point. An additional 75 fish were captured at Oliktok Point in early September. The fish from Bullen Point were larger (range = 283-430 mm, $\bar{x}$ = 356 mm, SD = 23.8 mm) than those

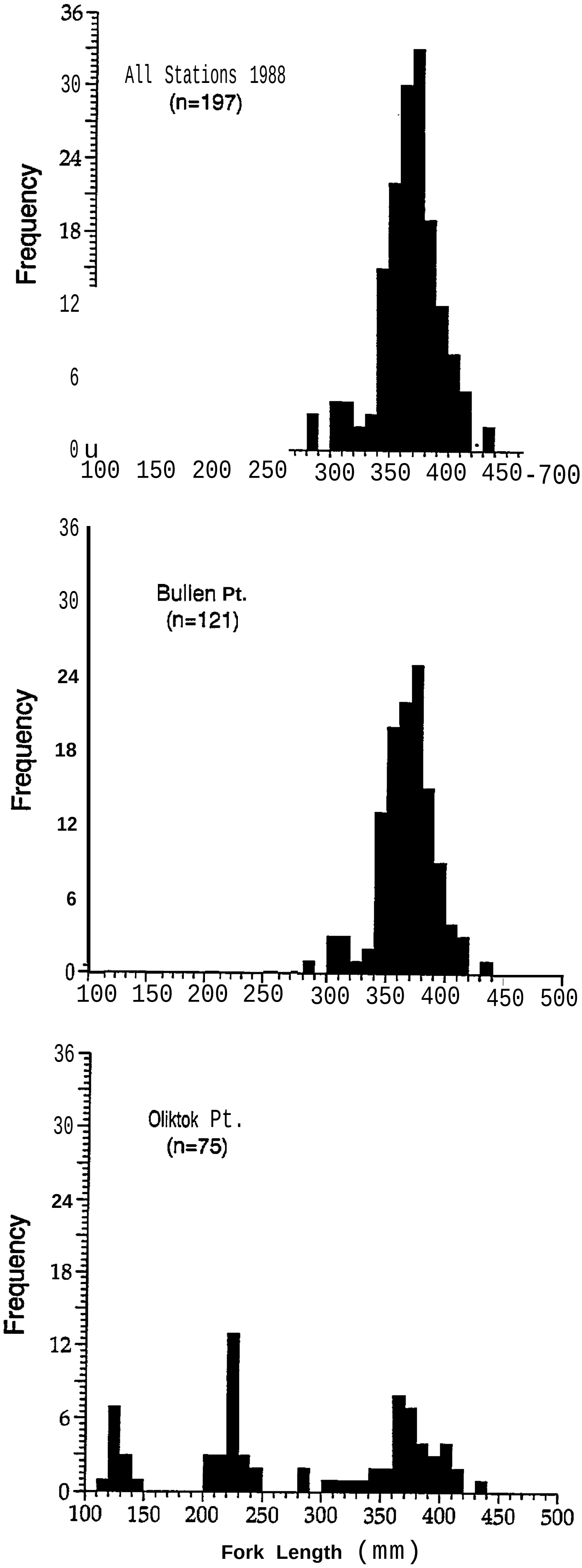

Figure 16.--Arctic cisco length **frequencies: total gillnet** catch, Bullen Point catch, and **Oliktok** Point catch.

at Oliktok Point (range = 111-431 mm, $\bar{x}$ = 285.6 mm, SD = 97.2 mm). Figure 16 indicates that the larger cohort observed at Bullen Point was still present in coastal waters a month later.

Size at Age

Cohort analysis and aging studies conducted by LGL (1989) on arctic ciscoes captured in 1988 identified the following size groupings and corresponding ages:

Cohort	***FL** Range*	*Age*
Cohort I	68-114 mm	0+
Cohort II	108-168 mm	1+
Cohort III	142-230 mm	2+
Cohort IV	>230 mm	>3+

Applying this classification to our combined catch data (n = 200), it can be seen that the catch comprised the following cohorts (in numbers of fish):

	Cohort			
Area	*I*	*II*	*III*	*I v*
Offshore	1	0	1	1
Bullen Pt.	0	0	0	122
Oliktok Pt.	1	10	19	45

An inspection of average size-at-age data for arctic ciscoes collected in Simpson Lagoon (Craig and Haldorson 1981) indicates that fish >200 mm were age 3+. Fish of lengths between 340 mm and 400 mm were aged anywhere from 6 to 12+ yr. If this relationship is considered in view of (1) our observed length frequencies, (2) information on maturity state (described below), and (3) age of first spawning(50% at age 8; see Craig 1989a), then the majority of ciscoes in our collection (340-400 mm) were ages 5-7. The age-length relationships for arctic ciscoes from Harrison and Prudhoe bays in 1988 (LGL 1989) suggest the likelihood of them being older fish (>7 yr).

Length-Weight Relationship and Condition

The following regression model described the length-weight relationship (Figure 17) for arctic ciscoes in our 1988 sample:

$$\ln (W) = 5.81 \times 10^{-'} + 3.91 \ln (L)$$

SE (a) = 0.4055
SE (b) = 0.08883
r = 0.977
n = 97

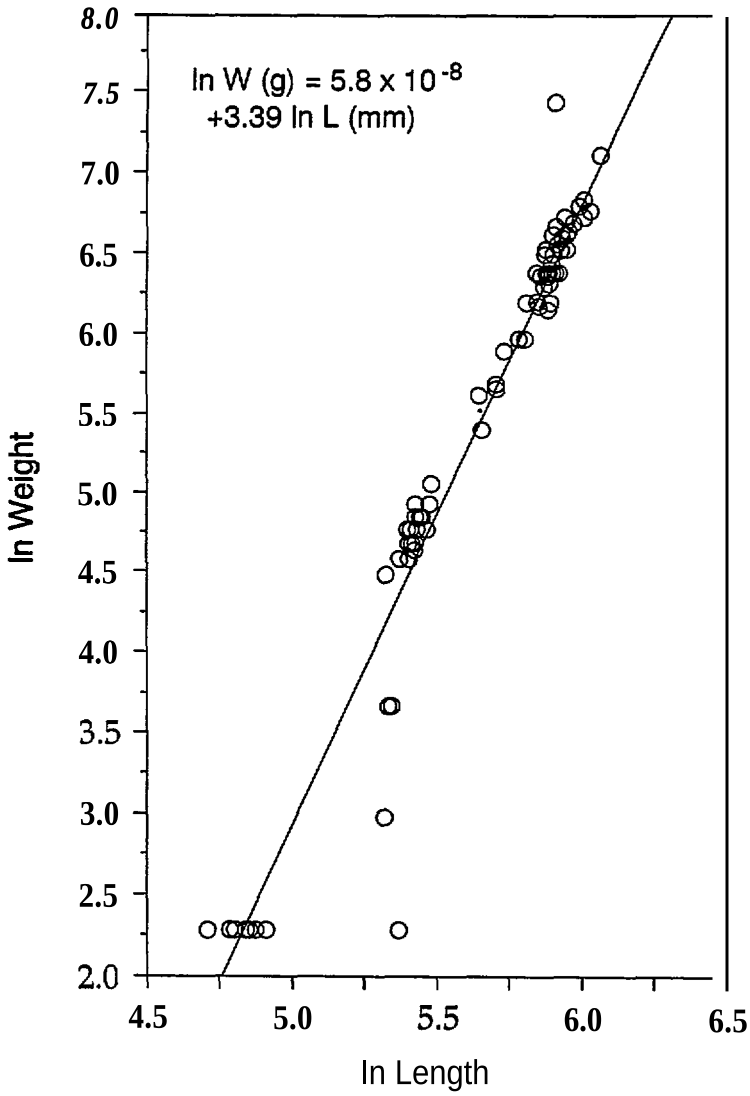

Figure 17.--Weight-length regression for arctic cisco.

The high value of b is suspicious and may reflect a selectivity bias of the gillnet for larger fish. Gillnet selectivity has been reported in Simpson Lagoon (Craig 1989a) and in Camden Bay (Fruge et al. 1989). Only 10 fish $<$ 200 mm long were captured by our gillnets in 1988 (5% of the catch). Carlander (1969) notes that regression slopes >3.5 cannot apply over a wide range of lengths without profound changes in body form.

Condition factors (Kn) were calculated for "early" (4–10 August) and "late" (2-6 September) portions of the open-water season. Mean Kn values of 1.06 and 1.02 were computed for the respective periods. No significant difference (Student's t, $P < 0.05$) was found between time periods.

Reproductive Status

Many ciscoes were released alive and thus only length measurements were obtained from a portion of the sample. Table 7 shows maturity state information from 117 fib. Although the 84-mm fish was not sexed it was obviously immature. The majority of ciscoes examined were immature and would not have spawned in 1988. Eleven fish appeared to have spawned previously.

Sex Ratio

An overall sex ratio (male:female) of 1:1.2 was observed in the combined catch data. Sex ratios were also compared between Bullen and Oliktok points. A ratio of 1.2:1 was found in the Bullen Point sample and 0.7:1 at Oliktok Point.

Food Habits

The stomach contents of 10 fish were examined from the Oliktok Point sample. In order of relative importance the diet was found to consist of mysids, unidentified larval fish, and young-of-the-year arctic cod. Several stomachs were noted as being 100% full (but not distended). These fish had been feeding on mysids. One fish displayed scars that were apparently the result of a seal attack.

Least Cisco

Length Frequencies

Least cisco lengths ranged from 103 to 388 mm (Figure 18). The average length was 333.4 mm. Least ciscoes were collected exclusively by gillnetting and large fish (>200 mm) were more heavily represented than smaller individuals in the catch. LGL (1989) fyke net data show fish in the 180-350-mm size range were most abundant in Prudhoe Bay in 1988 and our data are consistent with this observation.

Early and late season size comparisons are possible between least cisco catch data from Bullen and Oliktok points. Fifty-six fish captured during Cruise 1 at Bullen Point ranged in size from 22o to 345 mm ($\bar{x}$ = 288.2 mm, SD = 29.5 mm). Thirty-three fish sampled at Oliktok Point during Cruise 3 ranged from 103 to 388 mm ($\bar{x}$ = 276.9 mm, SD = 85.8 mm). Of the small fish (six fish c 200 mm) captured at Oliktok Point, all were less than 150 mm long (range = 103-146 mm).

Size at Age

Fish ages were estimated using the age-length relationship described for least ciscoes in Simpson Lagoon (Craig and Haldorson 1981). The fact that all fish examined

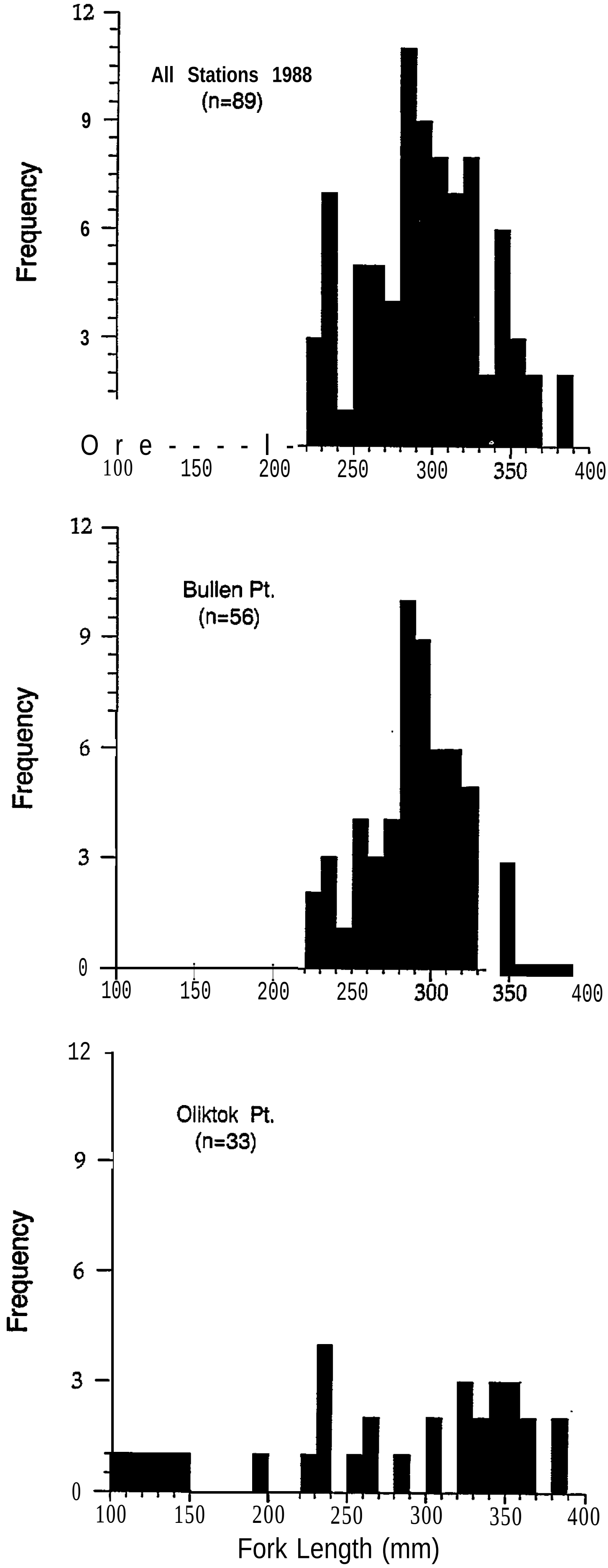

Figure 18.--Least **cisco** length frequencies: **total gillnet** catch, **Bullen** Point catch, and **Oliktok** Point catch.

were immatures (Table 7) suggests probable ages of 5-9 yr. Without actual verification of age (from otoliths or scales) this result is speculative. The Simpson Lagoon data show great variability in age at a particular size. Considering the imprecise nature of our gonadosomal index, it is possible that these least ciscoes were older (i.e., 10+ or more). Of the small fish (<150 mm) from Oliktok Point, five were likely age 2+ and one could have been age 3+.

Length-Weight Relationship and Condition

The length-weight regression (Figure 19) for least cisco in 1988 was:

$$\ln(W) = 3.278 \times 10^{-7} + 3.59 \ln(L)$$

$$SE(a) = 0.9555$$
$$SE(b) = 0.4714$$
$$r = 0.976$$
$$n = 33$$

The large value of the regression slope b (i.e., >3.5) may reflect the selectivity bias of the gillnets described previously.

A mean condition factor (Kn) of 1.08 was calculated for fish measured during Cruise 3. This index corresponds to fish condition observed during the late portion of the open-water season (n = 33). All fish on which this index is based were captured at Oliktok Point. There were not enough independent measures of length and weight taken at Bullen Point to compute a Kn in similar fashion. However, it was possible to estimate Kn for the "early" season using the sample mean $\bar{W}$ in conjunction with the regression-determined value for L. The total (bulk) weight of 52 least ciscoes sampled at Bullen Point was 12,850 g ($\bar{x}$ = 247.12 g). The calculated mean length is 293 mm. These values produce an estimated Kn of 1.05. The statistical difference between condition factors during early and late periods was not evaluated.

Reproductive Status

All fish examined (42 total) were immature and would not spawn in 1988. One-half of the least ciscoes were considered to be 1 yr away from spawning. The remaining 21 fish examined were estimated to be at least 2 yr from spawning. The six fish < 150 mm were at least 4-5 yr from sexual maturity.

Sex Ratio

Of 44 fish from which data were collected, females outnumbered males by a factor of 4.5. Sex ratios (male:female) were 1:3.7 at Bullen Point and 1:10 at Oliktok Point. Because of the small sample sizes these ratios should be viewed with caution.

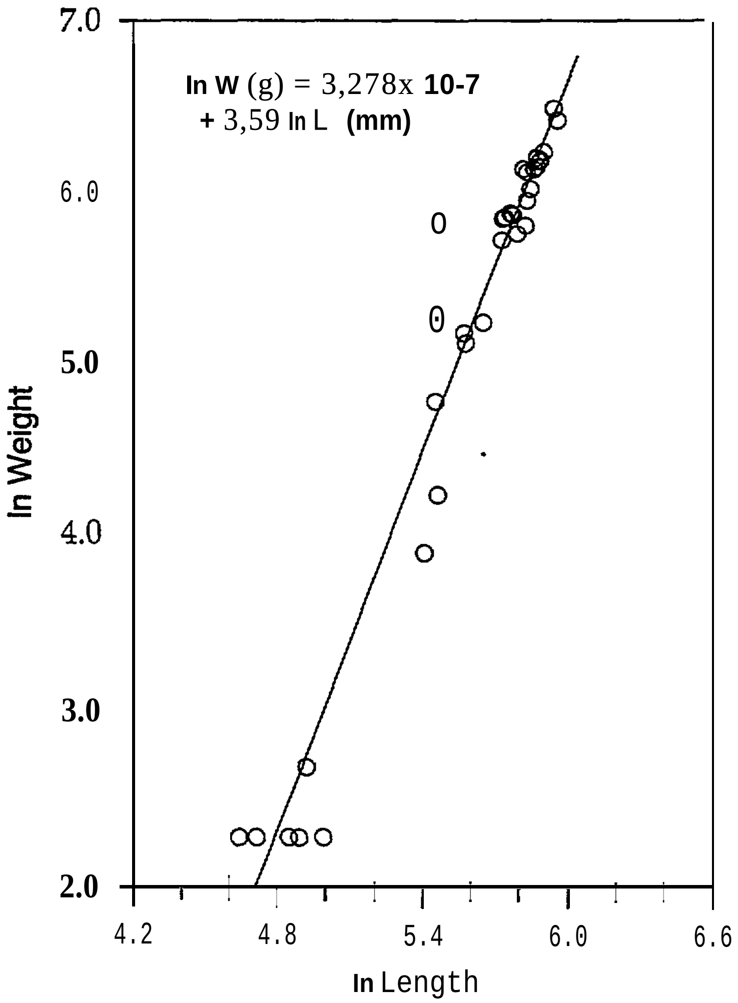

Figure 19.--Weight-length regression for least cisco.

Food Habits

The stomach contents of two least ciscoes captured at Oliktok Point were evaluated for food habits information. Both fish had been feeding on mysids and amphipods. These foods appeared to be of about equal importance in the least cisco diets.

Broad Whitefish

Length Frequencies

Only eight broad whitefish were captured in 1988 and all were taken by gillnetting. Three were captured at Bullen Point and five at Oliktok Point. Fish ranged in length from 320 to 445 mm (Figure 20}. The average length of fish collected at Bullen Point was 342 mm versus 385 mm in the Oliktok Point sample.

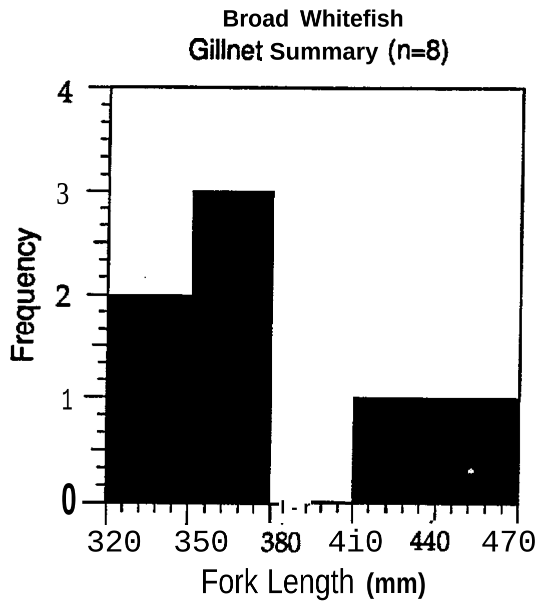

Figure 20.--Broad whitefish length frequencies, all stations combined.

LGL (1989) identified four cohorts of broad whitefish in Prudhoe and Harrison bays. Cohort IV (>230 mm) broad whitefish were abundant in their sampling near the Kuparuk River west of West Dock, at Heald Point, and in Foggy Island Bay. This cohort was the only one represented in our sampling.

Size at Age

The age-length relationship described for broad whitefish from Prudhoe Bay in 1988 (LGL 1989) was used to estimate age. Fish taken at Bullen Point ranged in length from 324 to 364 mm. This suggests probable ages of 7-9 yr. Oliktok Point fish were larger, ranging in size between 320 and 445 mm. These fish were probably 8-12 yr old,

Length-Weight Relationship

Regression analysis of the small sample of broad whitefish suggests the following relationship between length and weight variables (Figure 21):

$$\text{in}(W) = 2.067 \times 10^{-4} + 2.52\ \text{in}(L)$$

$$SE(a) = 0.9327$$
$$SE(b) = 0.4267$$
$$r = 0.986$$
$$n = 6$$

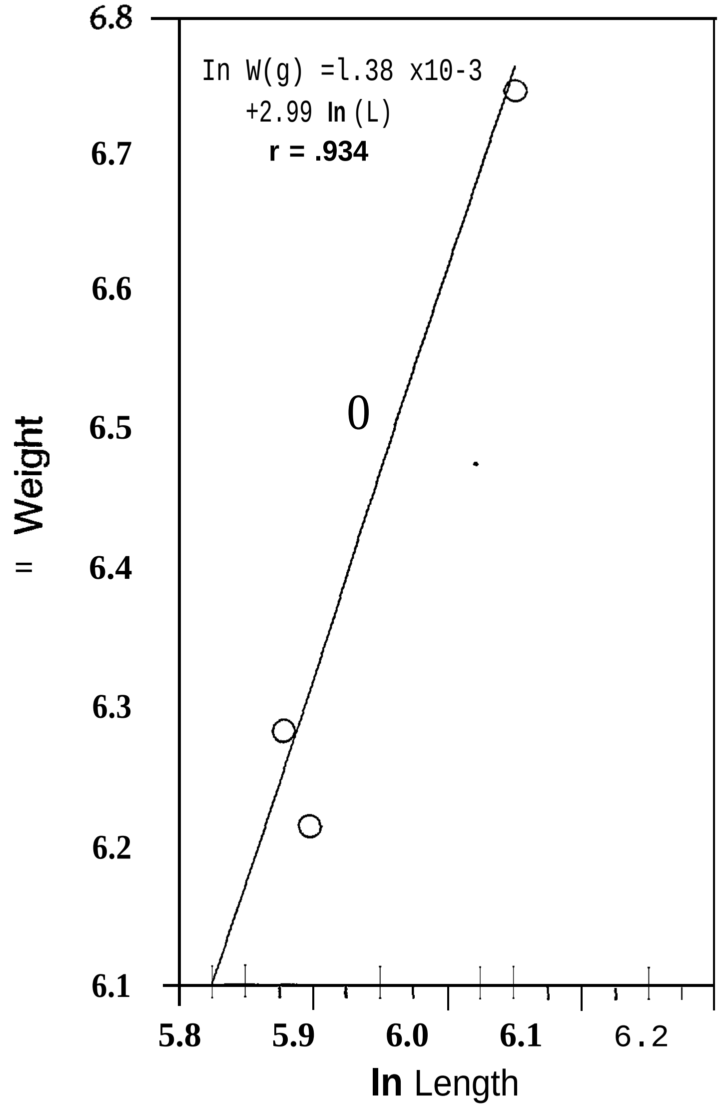

Figure 21.--Weight-length regression for broad whitefish.

Mean condition factors **(Kn)** of 0.78 for the "early" period at **Bullen** Point **(n** = 3) and 0.99 for the **"late"** period at **Oliktok** Point (n = 3) are suggested by our sample. Given the small sample sizes, these **Kn** values should not be construed as representative of the population. LGL (1989) suggests that larger broad whitefish may have dispersed more widely in 1988 than has been observed in previous years. The **Kn** values may reflect poorer environmental conditions (relatively cool temperatures and high salinities) for growth in 1988.

Reproductive Status

Four fish were examined for maturity condition with the following results: Ml - 320 mm; **M2** -425 mm; **F1** -338 mm; and Ml -324 mm.

Other

The small sample does not lend itself to presentation of sex ratios. No food habits information was collected.

Rainbow Smelt

Rainbow smelt were observed only in catches from Harrison Bay. A total of eight rainbow smelt were captured in gillnets fished at Oliktok Point during Cruise 3. Five fish were devoured by predatory amphipods while hanging in the net, leaving only skeletal remains. The three remaining fish and one additional smelt captured in the seine were measured for length. Gillnet-captured fish had lengths of 252 mm, 246 mm, and 247 mm and weighed 120 g, 183 g, and 130 g, respectively. These fish had been feeding on mysids at the time of their capture or while they were trapped in the net. The 247-mm smelt was an immature female (F2) that probably would not spawn for 2 yr. This was the only specimen from which information on sexual maturity was obtained. The seine-caught smelt was a small fish (133 mm) that was captured at an offshore station near the Colville Delta (A03119).

Arctic Cod

Length Frequencies

Arctic cod ranged in size from 22 to 147 mm long (Figure 22). The average length was 76 mm. The length frequencies are clearly bimodal with peaks between 25-30 mm and 80-90 mm in the September 3 sample (n = 350) taken at a station seaward of the Colville Delta (A03119). Conversely, in a large sample (n = 309) taken earlier in the season (August 5) in eastern Stefansson Sound (B02038), the distribution of measured lengths was unimodal, peaking midway between 60 and 90 mm. In two periods of offshore sampling in Camden Bay (l-2 August and 18-22 August) no cods < 60 mm or >95 mm were captured (n = 40). Fish > 100 mm long were apparently few at offshore stations located between the Endicott Causeway and Bullen Point in August as well as in Harrison Bay in early September.

Houghton and Whitmus (1988) report catching 695 arctic cod and 13,141 gadid larvae between 17 August and 3 September in Prudhoe and Foggy Island bays. The mean length of the 304 cod measured was 90 mm (SD = 15mm). More than 1,000 lengths were obtained from postlarval fish. Their mean length was 36 mm (SD = 24 mm).

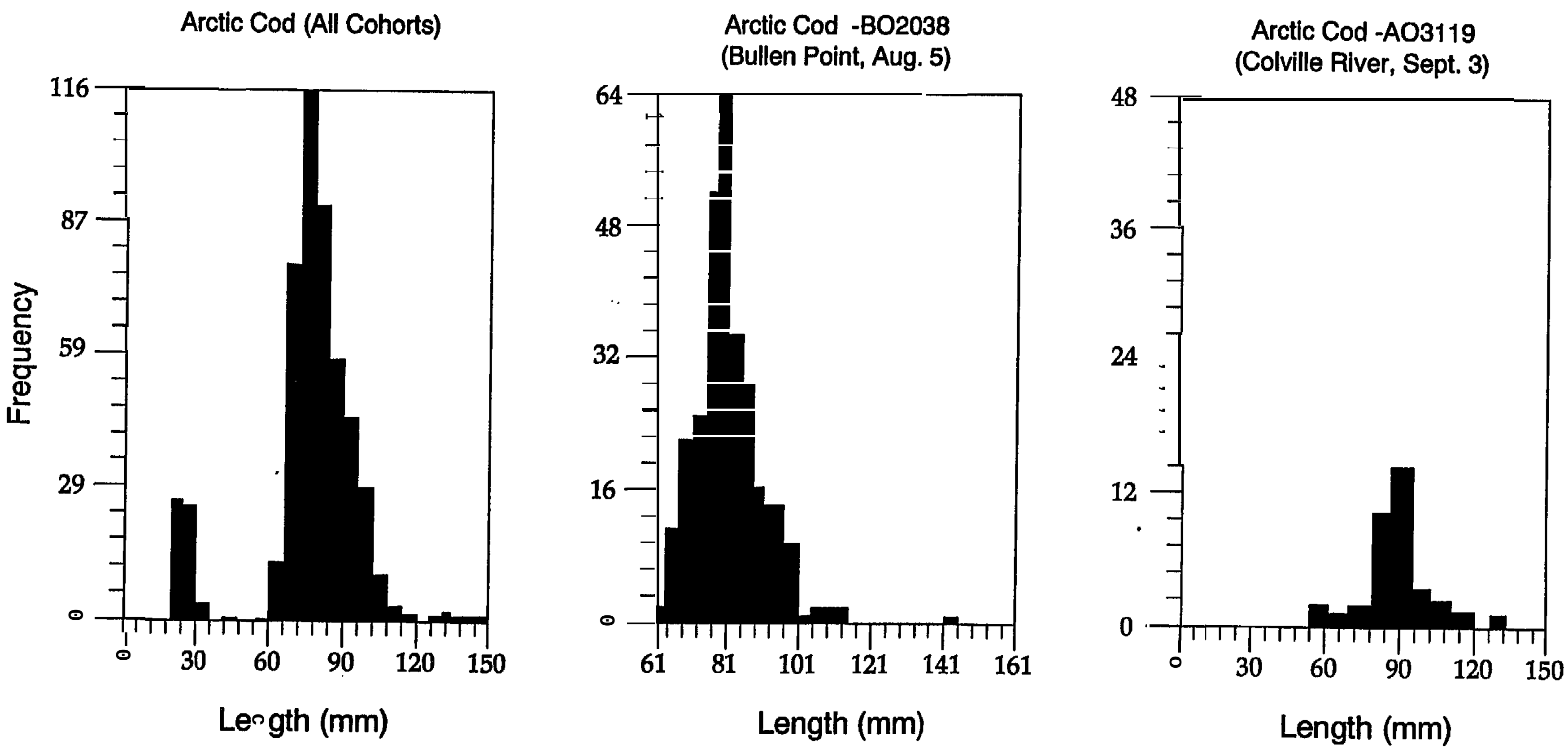

Figure 22.--Arctic cod length frequencies: all cohorts; offshore Bullen Point, 5 August; and Colville Delta, 3 September.

Size at Age

Age and growth relationships have been described for arctic cod in coastal Beaufort Sea waters between the Colville Delta and the Sagavanirktok River (Craig et al. 1982). Arctic cod < 60 mm were young-of-the year, 60-110-mm fish were age 1+, and 110–150-mm fish were age 2+ (or possibly 3+).

Capelin

Length Frequencies

Capelin ranged in size from 38 to 84 mm and averaged 52 mm long (Figure 23). The fish were all captured at stations of approximately 5. O-m depths near large river mouths. On 11 August two capelin ($\bar{x}$ = 64 mm) were captured off Bullen Point east of the Sagavanirktok River (BO3068-69). In sampling conducted off the Canning River in Camden Bay on 22 August, an estimated 675 capelin ($\bar{x}$ = 63 mm, range = 50-84 mm) were captured in the seine. More than 1,900 capelin were captured on 3 September at two stations off the Colville Delta (A03117 and A03119). These fish ranged in size from 38 to 80 mm and averaged 69 mm (n = 201) and 63 mm (n = 340), respectively.

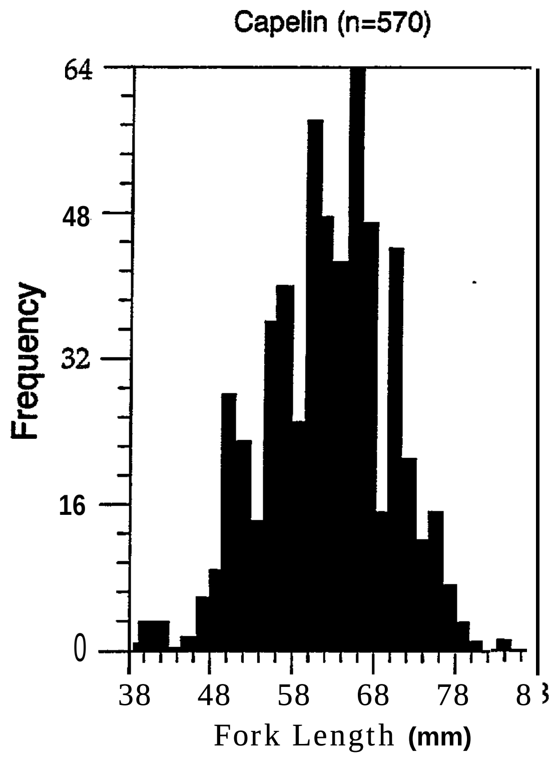

Figure 23.—Capelin length frequencies, all cohorts.

Houghton and Whitmus (1988) caught nearly 16,500 capelin in Prudhoe and Foggy Island bays in late August 1988. The mean length of the 480 fish measured was 61 mm (SD = 7 mm).

Size at Age

Pahlke (1985) described age-length relationships for capelin in the Kodiak, Togiak, and Nome areas. Only one fish smaller than 110 mm FL was included in his analysis. Age composition, average length, and average weight were significantly different between study areas and varied from year to year. At a given age, males were larger than females. The capelin ranged in age from 2 to 4 yr, with age 3 predominant. Most of the small (>40 mm) fish *were* probably yearling fish. It is possible that the capelin < 40 mm reported here, and by Houghton and Whitmus (1988), were young-of-the-year fish.

Other Species

Small numbers of several other species were collected in 1988. Incidental catches included three Pacific sandlance, ten lipariid snailfish, one ninespine sticklebacks, and 22 sculpins. Length-weight information on these species is provided in Table 6.

The Pacific sandlance were captured off of the Colville Delta in an area where the seafloor is composed of coarse-grained sands. The only sandlance examined for gut contents had been feeding on mysids. Nine snailfish were captured near the Boulder Patch in Stefansson Sound. One was seined in Camden Bay. Houghton and Whitmus (1988) reported high densities of larval snailfish in offshore stations in Foggy Island Bay. One ninespine sticklebacks was captured in a westward-facing set (5.5-m depth) in eastern Camden Bay on 21 August (CO4081). The sticklebacks capture occurred after several days of sustained easterly winds (a period of upwelling) and sea surface temperatures were very cold (–0.4°C) at the capture site.

Fourhorn sculpins were captured in both gears at sampling stations located throughout the study area. Two other sculpin species, the arctic hookear and arctic staghorn sculpins, were captured at offshore stations near the Boulder Patch. Of the fourhorn sculpins examined for maturity condition, one fish (FL = 181 mm) appeared to have spawned during the preceding year. Two other fourhorn sculpins (a 203-mm male and a 198-mm female) were considered to be immature fish 2 yr away from spawning. Amphipods were observed in the guts of fourhorn sculpins captured at Bullen and Oliktok points.

Amphipod predation on net-caught fish from the west side of Oliktok Point was extreme. Even though nets were checked every 2 hr, several whitefish were rendered unidentifiable to species.

Tagged Fish

Four tagged fish, one broad whitefish and three least ciscoes, were captured at Oliktok Point. Unfortunately, their poor condition after gilling precluded release. Information on the tags was given to the Division of Fisheries, FWS, Anchorage, Alaska, and is tabulated below:

Fish	*Date*	*Tag type*	*Number*	*Scar*
Least	9/2	Blue Floy anchor	LGLFRBK 043696	Abscessed
Broad	9/4	(Tag lost earlier in year)		Open wound
Least	9/6	Yellow dart	WCC8217526	Fair
Least	9/6	Red dart	Environo 15827	Good

It was noted that the LGL-marked fish had eggs measuring 1 mm in diameter.

Zooplankton

Seven surface bongo tows were completed in 1988. The stations selected for plankton sampling were located seaward of the barrier islands of Stefansson Sound (B04025, B04025, and A03136), off the Colville Delta (A03115), offshore Barter Island (DO1OO2), and in the deeper waters of Camden Bay (C04086). The purpose of the sampling was only to obtain information about the presence/absence of zooplankton species (and their sizes) at several offshore locations. Secchi disc readings taken at the plankton stations indicated an average depth of light penetration to be 2.31 m (range = 0.5-3.99 m, SD = 1.39).

The zooplankton samples have not been sorted. However, the sample collected beyond the McGuire Islands in eastern Stefansson Sound on 8 August contains an unidentified larval fish (suspected gadid). The sample collected off the Colville Delta on 3 September is full of mysids.

Archival Specimens

Voucher specimens of several fish species were sent to the California Academy of Sciences to be incorporated into the OCSEAP collection. The species sent include capelin, rainbow smelt, arctic cod, snailfish, arctic hookear sculpin, and arctic staghorn sculpin.

Habitat Use

Of the purse seine sets that were successfully completed, 27 occurred in coastal waters, 14 in transitional waters, and 1 in oceanic waters (Figure 24). The number of successful sets per sampling period was 30, 10, and 2, respectively. No fish were captured at the oceanic station, so it has been dropped from analysis herein. Assuming that these

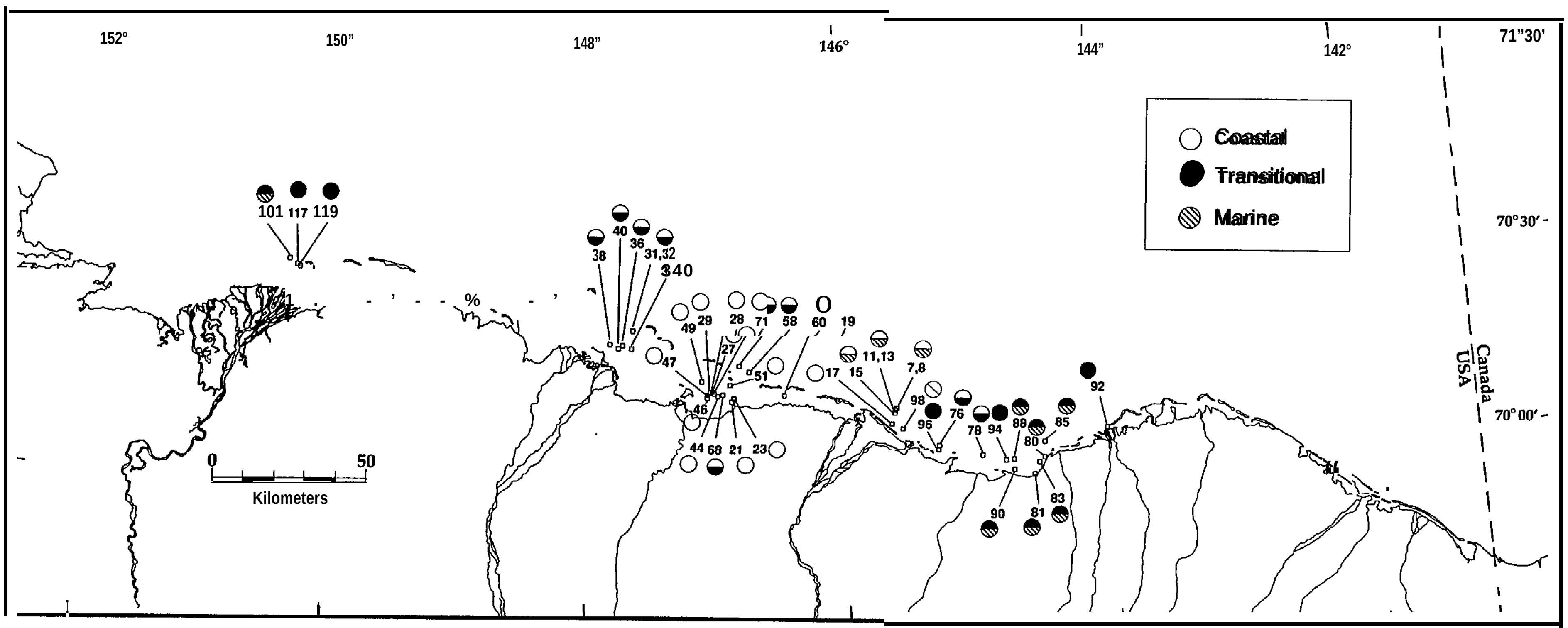

Figure 24.--Distribution of coastal, transitional, and marine water masses in the 1988 seine sampling program (water masses identified by numeric portion of the cast number).

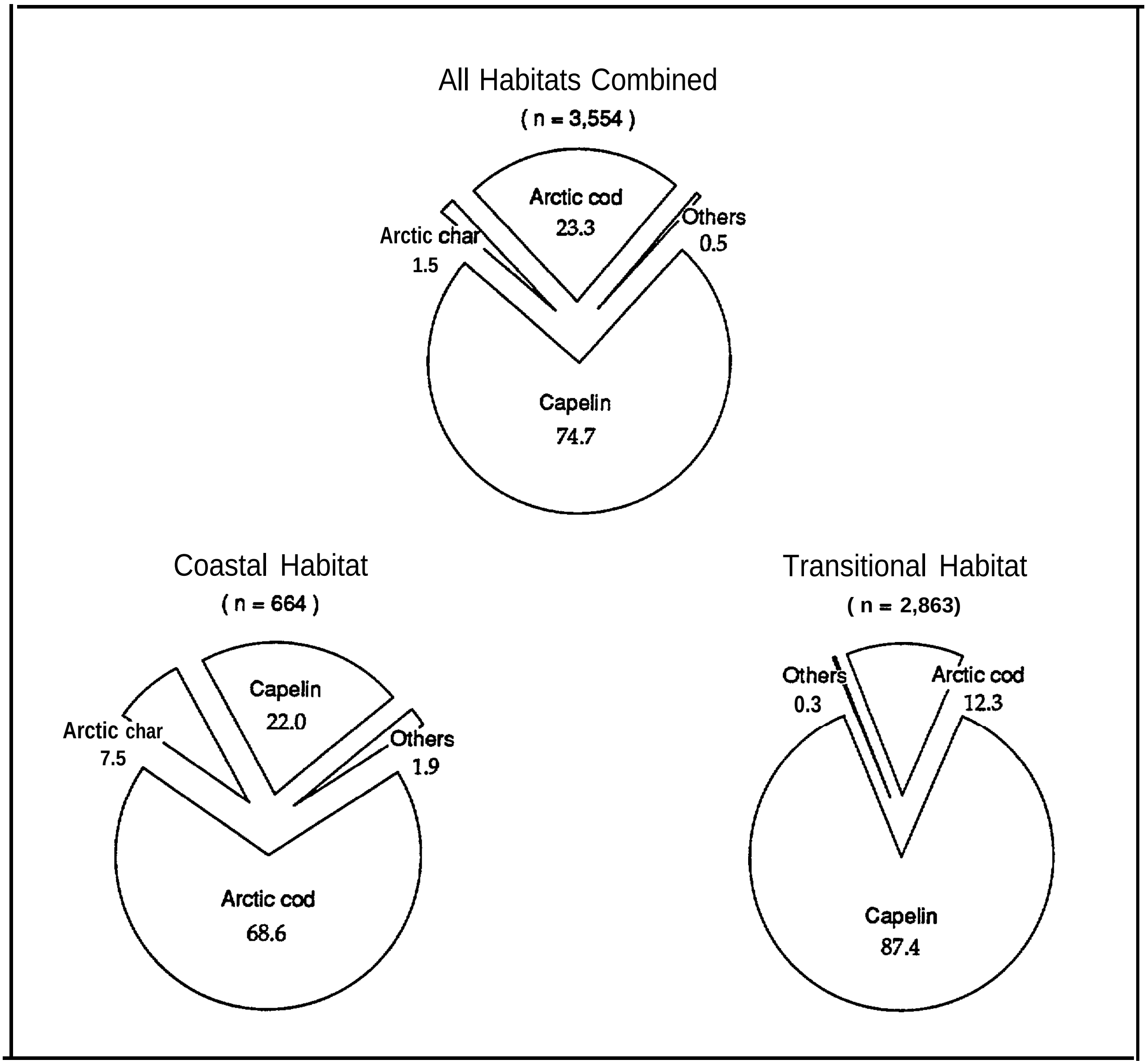

Figure 25.--Percent species composition of seine catch by **hydrographically** defined habitat-type: all habitats combined, coastal habitat, and transitional habitat.

water masses reflect habitat-types, the seine catch was distributed (% composition) as shown in Figure 25. The total number of fish (3,554) includes a small **number** of fish reported in aborted hauls. The category "Others" refers to the small catches (combined seine catch <5%) of **snailfish, sculpins,** arctic **cisco,** Pacific **sandlance,** sticklebacks, and rainbow smelt.

Contrary to expectation, no **anadromous** fish were caught at six stations in coastal waters having temperatures > 6°C. The mean surface temperature at coastal water stations during 1988 was **5.6°C.** This average temperature is biased toward conditions in early August when most sampling occurred. This was also the only period during which anadromous fish were captured by seining.

The physical properties of the upper mass (waters above the pycnocline) were described because of its known utilization by anadromous species. Test gillnet fishing in Camden Bay (Fruge et al. 1989) demonstrated consistently higher catches of arctic char and other anadromous fish in the upper 2.4 m. Presumably, this pattern of use can be extrapolated to other coastal areas of the Beaufort Sea. However, it is recognized that actual depth of occurrence will depend on temperature and salinity conditions at a given location, and activity of the fish.

The ranges of **temperature and salinity values presented above for the upper water mass represent depth-integrated means for these parameters. In four cases, the inclusion of deepwater stations in the coastal category reflects the depth of the upper mass (essentially coastal water) being deeper than the seine. A result of this action is a disproportionate effect on the bottom temperature and salinity characteristics of the coastal habitat. If these stations are excluded from the temperature and salinity calculations, the means above are 1.9°C and 15.1 ppt, respectively.**

Chi square (χ^2) analysis was used to test the null hypothesis that there was no significant difference ($P < 0.05$) in the frequencies of fish occurrence in coastal and transitional waters. Occurrence data were weighted by effort expended in each habitat type. Observed and expected occurrences of fish by habitat are shown below.

	Coastal		*Transitional*	
Species Group	*Observed*	*Expected*	*Observed*	*Expected*
All species	17	16.5	8	8.5
Anadromous fish	2	2.6	2	1.4
Estuarine group	6	7.3	4	3.7
Marine fish	14	12.5	5	6.5

The "anadromous fish" group consists of arctic char, arctic cisco, rainbow smelt, and ninespine sticklebacks. The "marine group" includes arctic cod and sculpins. The "estuarine" grouping is an arbitrary clustering of the remaining species. No statistical difference in habitat utilization by the all species group ($\chi^2 = 0.056$, 1 df) or marine group ($\chi^2 = 0.526$, 1 df) was evident in our data. There were insufficient data to conduct χ^2 tests on anadromous and estuarine groups.

Although anadromous species were encountered offshore in our purse seining and in tow-netting by others (Houghton and Whitmus 1988), the limited sampling effort and small sample sizes preclude definitive conclusions about observed inshore-offshore distributions and habitat use. For example, if our sample was 50 stations, distributed in coastal, transitional, and oceanic habitata, the power of the χ^2 test ($P < 0.05$, df = 2) would have been 70%. The corresponding "effect" of habitat on fish frequency of occurrence would be 40% of the mean. The sample would be large enough to show a significant difference equal to 40% of the mean in about 70% of the cases. At this power, a Type II error would be committed 30% of the time.

DISCUSSION

The summer of 1988 was characterized as a "heavy ice year." Breakup occurred on the North Slope in mid- to late July but the ice pack remained close inshore throughout the "open water" season. From the perspective of requirements for offshore seining, the open-water period was even more abbreviated, extending from 1 August to 10 September.

Vessel movements were restricted in 1988 by harsh environmental conditions. While we were able to seine throughout the zone of maximal brackish water influence discussed by Craig (1989a), ice and frequently bad weather, as well as the long distances and travel times required to reach prospective fishing grounds, had an adverse effect on the number of stations we were able to occupy.

Length frequency information from the anadromous fish species captured in the seine indicate that larger-sized fish (400-mm range) were sampled by the gear. Size-related avoidance problems have been reported for many other active sampling gears but were not apparent with the seine. For example, Isakson et al. (1986) reported gear avoidance by juvenile salmon (FL > 140 mm) in exploratory tow net fishing in Bristol Bay. Similar gear avoidance by arctic species may also be reflected in the size composition of the tow net catches of Houghton and Whitmus {1988). The use of a "round haul" technique in conjunction with electronic fish finding methods may improve the efficiency of the seine operation from what occurred in 1988. The potential for tactile as well as visual avoidance would be reduced by this sampling approach.

Although the magnitude of active sampling effort was less than anticipated in 1988, the analysis of fish habitat use that we employed can be readily adapted to multiyear data sets. This approach has recently been used by Rose and Leggett (1989) in a study of Atlantic cod abundance patterns relative to water mass distributions and prey density fields in the North Atlantic. Frequency of occurrence data collected in different years are statistically comparable as long as the hydrographic definitions used in habitat characterization remain consistent. If electronic gear is used to locate fish, hydrographic casts would need to be completed after the seine set to reduce bias associated with frequency of habitat-type sampled; i.e., these would be "blind" seine sets with respect to knowledge of the water mass sampled.

Hale (1989) analyzed meteorological and oceanographic data sets acquired by the FWS in 1988 from three coastal locations in the ANWR segment of the eastern Beaufort Sea. The data were acquired from 6 August through 13 September. His analysis showed winds to be predominantly from the east (60%) with westerly winds occurring about 30% of the time. Mean wind speeds of 5 m/sec were reported. A comparison of nearshore and lagoonal hydrographic data sets shows that water temperatures rarely exceeded 7*C in coastal bays and lagoons during 1988. Little vertical stratification was observed in shallower portions of lagoons and protected bay environments. Salinities were generally less than 9 ppt at these locations.

More exposed sampling sites, such as Bullen Point, may have been subject to greater habitat variability resulting from wind-induced mixing. Offshore coastal stations (5–10 m deep) inside the barrier islands, or more exposed locations, tended to be stratified in two layers. In many instances, the waters overlying the pycnocline were of similar temperature and salinity composition to those much closer to the coast. This feature of the two-layer system provides a possible offshore extension of the more limited brackish water available to anadromous fish.

Storms dominated the open-water period after mid-August, and this may have shortened the period of seasonal use of exposed coastline by anadromous fish. A comparison of 1987 and 1988 fyke net catches at Collinson Point in Camden Bay (unpublished FWS catch statistics) shows a marked increase in arctic char catches (142 vs. 543 fish, respectively) in the latter year. The concept of increased use of protected bays and lagoons by fish during unfavorable conditions is intuitively appealing.

Arctic char were the primary target of our offshore purse seining. Their relative availability must therefore be considered in view of the success, or lack thereof, of the offshore sampling effort. Catch statistics from the eastern Beaufort Sea (Fruge et al. 1989) show greatest relative abundance of char in coastal waters from mid-July to mid-August 1988. LGL (1989) reported peak char abundance in Prudhoe Bay in early (around 15 July) and late (around 1 September) periods in 1988. The peaks in CPUE observed by LGL were attributed to (1) their sampling near major char rivers, and (2) the wide-ranging dispersal of char during summer months. Essentially, these CPUE peaks coincide with arctic char departures from and returns to freshwater habitats. LGL (1989) also reported very low catches of arctic char in the Harrison, Phillips, and Mckinley bay regions for similar summer periods in 1988. In the latter instances, the apparently reduced abundance of arctic char was explained by physiographic characteristics of the species' distribution.

In light of the above, two points are clear: (1) the coastal residency period for most char was 1.5 months in 1988, and (2) there was a reduced availability of arctic char in coastal waters after September 1. Spawning fish of the year were not expected, or encountered, in catches after mid-August. Arctic char were captured in offshore seining only during the fist half of August. Considering the seasonal availability of the species, and the logistical constraints imposed on offshore fishing in 1988, our catches indicate that seining is a practical sampling method for arctic char in the arctic marine environment.

Craig (1989a) indicated that the primary brackish water habitat of char extends some 2-10 km from the coast. The presence of arctic char beyond the inshore habitat may reflect directed movements related to feeding. Certain seine data support this. Four char

(297-385 mm long) captured in outer Mikkelsen Bay on 4 August appeared to be actively feeding, as they were satiated with larval snailfish. The water column there was well mixed (5-m depth, 3°C temperature, and 13-14 ppt salinity). On 11 August, 48 smaller char (range = 197-283 mm, $\bar{x}$ = 220 mm) were captured in seining 5 km offshore in Mikkelsen Bay. This may have been their first year at sea. These fish had undigested mysids and young-of-the-year arctic cod in their stomachs and may have been actively pursuing prey when captured. On this date the water column was stratified, with water temperatures and salinities in the upper layer of >5°C and 13 ppt, respectively.

Our results support an existing conceptual model of lagoonal/coastal use by arctic char (Irvine and Meyer 1989). Arctic char may undertake daily (or otherwise intermittent) excursions into offshore areas in search of food. Larval fish and young aged arctic cod and capelin may be a relatively more abundant food resource offshore, especially in the "early" season prior to the first marine intrusion. After feeding at offshore sites, the char may return to warmer inshore waters for enhanced metabolism or protection from storm events. Metabolic benefits of warmer temperatures also may be achieved via fish occupation of upper water layers which, in many instances, possess water property characteristics similar to inshore waters. With respect to new information, the apparent schooling of relatively large numbers of small char in offshore areas was an unexpected result. Perhaps it reflected interspecific competition for a limited inshore food resource.

The Mikkelsen Bay char sample served as a "blind test" of the GSI, as no information was provided to the FWS regarding "location of catch." The GSI's recognition of Sagavanirktok and Canning river fish, and proportionately higher assignments of these stocks to the mixture, is a confirmation of the validity of this technique. Arctic char from the eastern Beaufort Sea and Canada were also indicated in the sample. This is reasonable in light of known physiographic distributions and migration rates of char. The result is also supported by tag return data. The smaller-sized char in the large offshore sample (48 fish) were probably Sagavanirktok or Canning River fish undertaking their first seaward migration.

Our seining and gillnet fishing activities offer little new information about anadromous fish distributions. Length frequency data for arctic char, arctic and least ciscoes, and broad whitefish were similar to those reported by others (Fruge et al. 1989; LGL 1989). Arctic and least ciscoes of intermediate sizes (200-325 mm and 175-275 mm, respectively) were not abundant in our sampling. Like Houghton and Whitmus (1988), we captured very few small (<100 mm) arctic cisco at the offshore stations. Fruge at al. (1989) also reported a paucity of young-of-the-year arctic ciscoes along the ANWR coast. LGL (1989) indicated that 1988 was a poor recruitment year for the species.

Length frequency data obtained for arctic char captured in eastern Stefansson Sound are suggestive of the bimodal trend reported by LGL (1989). These authors offer two possible explanations for the observed bimodality. The first relates to energetic. A significant fraction of energy intake of immature anadromous char is presumably devoted to somatic growth rather than accumulation of fat reserves for overwintering. Overwintering mortality due to depletion of fat reserves may be higher among immature fish than adults, especially during winters when conditions during the preceding growth season were suboptimal. The second explanation relates to density dependence. Dillinger and Gallaway (1989) suggest that recurrent bimodal length frequency distributions of broad whitefish observed near Prudhoe Bay during the period 1975-88 may have resulted from high densities of large fish using critical freshwater overwintering and rearing habitats in some years. Large fish are presumed to exclude smaller fish from the preferred habitats. It follows that during years when exclusion of small fish occurs, relatively high mortalities of those age classes would result as the immature fish would be forced to use less hospitable habitats.

The bimodal size distribution of arctic char may also be a reflection of differential mortality related to feeding mode. Gallaway (1988) suggests that once char attain a certain size and morphology threshold and are able to feed on arctic cod, they have access to an often abundant food resource unavailable to smaller char. Small capelin reported in abundance offshore also may be an important food resource. Piscivory may confer significant energetic advantages over planktivory in terms of energy expended per unit of energy captured, thereby effectively reducing size-related mortality.

A probable consequence of the heavy sea ice coverage in 1988 was reduced use of coastal habitats by andromous fish. preliminary data of the FWS indicate a 10-fold reduction in total catch in 1988 relative to that in 1987. This was so despite a doubling of fishing effort in 1988. Cooler water temperatures and frequent storms probably resulted in the physical disruption and decrease of inshore habitat quality and accessibility. Fechhelm et al. (1989) found that colder temperatures and increased salinities may block migratory pathways of anadromous fish. From a population perspective, growth parameters could be affected by cooler temperatures and reduced feeding opportunities.

Such effects are not readily apparent in Kn values reported for arctic char or arctic and least ciscoes in 1988 (Fruge et al. 1989; this report). In Norway, Berg and Berg (1989) found that the earliest portion of the "open water season" corresponded to the period of greatest seasonal growth in arctic char. The temperature and salinity regimes reported by Hale (1989) for shallow water environments after mid-August are not unlike conditions reported by Schmidt et al. (1989) at fish overwintering sites. With respect to char, most fish had returned to freshwater habitats by early September. LGL (1989) noted a significant difference in the regression slopes of the weight-length relationships for broad whitefish in "early" and "late" periods of 1988. This was related to colder temperatures and higher salinities in autumn.

Young-of-the year (larvae to 30-40-mm juveniles) and yearling (60-90 mm) arctic cod were abundant in eastern Stefansson Sound during 1988 (Houghton and Whitmus 1988; this report). This is a known spawning ground nursery area significant for arctic cod (Craig et al. 1982; Craig 1984). The presence of young-of-the year juveniles near the Colville Delta in the seine sampling suggests the possibility of another spawning location in the western part of the study area.

Expatriate biota from the Chukchi Sea maybe transported as far east as Harrison Bay during periods of extended westerly winds. Arctic cod hatched in the Chukchi Sea could potentially be transported to this region. Fish-of-the-year were observed in catches in the northeastern Chukchi Sea during early September 1989; this area could be a potential source of young-of-the-year cod observed off the Colville Delta (W. Barber, Univ. Alaska Fairbanks, pers. commun.).

However, it seems more probable that the small cods observed in the September sampling originated in eastern Stefansson Sound. If one assumes (1) that cod spawn in spring some 167 km east of the Colville Delta, and (2) average summer conditions of 5 m/see easterly winds and 15.4 cm/sec currents prevail, it would take 7-19 days for a passively drifting "particle" to be transported into Harrison Bay. This scenario factors no west winds into the transport process. West winds, which occur about 30% of the time, tend to be stronger than east winds, and thus their effect on a passively drifting organism (in the opposite direction) would be greater. It is therefore not unrealistic to imagine an "estuarine transport" period encompassing the entire open-water period in which young cod are moved by currents from one end of the lagoon to the other, Mortality of post-spawners (2- and 3-yr-old fish) is apparently great, as few fish of older age groups (>120 mm) are reported in the various 1988 catch data (Houghton and Whitmus 1988; Fruge et al. 1989; this report).

A large number of very small capelin (<100 mm) were captured at several offshore locations in 1988 (Houghton and Whitmus 1988; this report). Spawning by capelin had previously been reported in Prudhoe Bay (Bendock 1979), and may also occur in Demarcation Bay (R. Bailey, FWS, pers. commun.). Subsistence use records indicate the species is present in coastal waters near Barrow during August but it is not known whether spawning occurs at this time. Large capelin are apparently rarely captured in coastal fish sampling (see, e.g., Craig and Haldorson 1981; Fruge et al. 1989). Although this may be an artifact of the sampling gears and areas fished, it is more likely a reflection of this species' requirements for offshore transitional or marine habitats.

In 1988 capelin were the most abundant fish we captured in pelagic habitats near the Canning, Sagavanirktok, and Colville deltas. Perhaps capelin spawn along the margins of these large river deltas and their larvae are subsequently transported offshore at the time of hatch. Alternatively, we think it more likely that spawning occurs farther offshore along the outer beaches of the barrier islands. Beach and offshore spawning are probable, the magnitude of either being related to the density of the spawning biomass. This hypothesis is consistent with Bendock's (1979) observations in Prudhoe Bay and what has been reported in the Northwest Atlantic (e.g., Carscadden et al. 1989).

The timing of capelin reproduction in the southeastern Beaufort Sea is poorly defined. It may occur in several waves at various times and places throughout the summer (Pahlke 1985). However, it is likely that reproduction is keyed in time and space to other events associated with spring breakup (e.g., warming temperatures and increasing food resources; see Chambers and Leggett 1989). Eggs hatch near mid-July and larval fish may be transported inshore under west wind conditions associated with the disintegration of the strong front between coastal and marine waters. A similar transport mechanism involving wind-regulated water mass replacement and transport of larval fish has been suggested for capelin off the coast of Newfoundland (Frank and Leggett 1982). In this case, the onshore transport would carry larvae into coastal "safe sites" where survival may be enhanced. Fish acoustically detected by Moulton and Tarbox (1987) along the leading edge of the front near Prudhoe Bay may have been capelin.

The hypothesized onshore transport (and possible movement of age 1 fish) of capelin would link early life history development in the species to favorable temperature and food conditions in the more protected nearshore zone. As indicated parenthetically above, it is not known whether the capelin overwinter in coastal waters or offshore. Existing information on the food habits of the capelin (Pahlke 1985) indicates copepods and euphausiids are their primary prey. As such, the species provides a trophic link similar to that described for arctic cod between the zooplankton and apex vertebrate consumers in the arctic. There is no reason that this fish would not be an important food resource for anadromous char and cisco species utilizing offshore habitats.

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Appendix A
Molluscs Collected in the Beaufort Sea in 1988

BIVALVIA

Astarte montagui (Dillwyn, 1817)
Axinopsida orbiculata (G. O. Sars, 1878)
Boreacola vadosa Bernard, 1979
Crytodaria kurriana Dunker, 1862
Diplodonta aleutica Dan, 1901
Hiatella arctica (Linnè, 1767)
Liocyma fluctuosa (Gould, 1841)
Lyonsia arenosa (Möller, 1842)
Macoma calcarea (Gmelin, 1791)
Macoma crassula (Deshayes, 1855)
Macoma moesta alaskana Dall, 1900
Musculus (Musculus) corrugatus (Stimpson, 1851)
Musculus (Musculus) discors (Linnè, 1767)
Musculus (Musculus) niger (Gray, 1824)
Mya (Mya) pseudoarenaria Schlesch, 1931
Nucula tenius (Montagu, 2808)
Pandora **(Pandorella) glacialis** Leach in Ross, 1819
Portlandia arctica {Gray, 1824)
Tellina nuculoides (Reeve, 1854)
Thyasira equalis (Verrill & Bush, 1897)
Tridonta borealis (Schumacher 1817)
Yoldiella (Yoldiella) intermedia (M. Sars, 1865)

GASTROPODA

Admete sp. #850
Amauropsis islandica (Gmelin, 1791)
Boreoscala greenlandica (Perry, 1821)
Buccinum angulosum Gray, 1839
Colus dautzenbergi Dan, 1916
Cylichna occulata (Michaels, 1841)
Diaphana minuta (Brown, 1827)
Margaritas **giganteus** (Leach, 2870)
Natica (Cryptonatica) russa Gould, 1859
Neptunea borealis (Philippi, 1850)
Neptunea heros (Gray, 1850)
Odostomia (Menestho) albula (Fabricius, 1780)
Odostomia (Menestho) castanea (Möller, 1842)33
Oenopota novajasemliensis (Leche, 2678)
Oenopota roses (G.O. Sars, 1878)
Oenopota simplex (Middendorff,1849)
Oenopota sp. #679
Oenopota sp. #843
Philine polaris Aurvillius, 1885
Polinices pallida (Broderip & Sowerby, 1829)
Retusa sp. #844
Velutina undata Brown in Smith, 1839
Velutina velutina (Müller, 2776)

1988 COLLECTION STATIONS.
BEAUFORT SEA, ARCTIC OCEAN, NOAA-OAS

88-1 B04:019; 4:VIII:88; 70 12.6'N, 146 27.6'W; 4.5m
Oenopota novajasemliensis - 2
Musculus discors - 1
Musculus niger aead
Liocyma fluctuosa - 15
Pandora glacialis dead
Crytodaria kurriana dead
Musculus corrugatus - 4
Axinopsida orbiculata - 1

88-2 B04:021; 4:VIII:88; 70 11.5'N, 146 52.3'W; 4.5m
Oenopota novajasemliensis dead
Musculus niger - 2
Liocyma fluctuosa - 2
Tridonta borealis dead
Macoma moesta alaskana dead
Astarte montagui dead
Portlandia arctica dead

88-3 B04:022; 4:VIII:88; 70 12.0'N, 146 51.7'W; 6.5m
Cylichna occulata dead
Oenopota novajasemliensis - 6
Odostomia albula - 5
Musculus discors - 1
Liocyma fluctuosa - 4
Tridonta borealis - 4
Macoma calcarea dead
Astarte montagui - 6
Portlandia arctica - 1
Diplodonta aleutica - 1

88-4 B04:026; 4:VIII:88; 70 13.1'N, 146 59.8'W; 6.0m
Retusa sp. #844 dead
Liocyma fluctuosa - 1
Astarte montagui dead

08-S B02:030; 5:VIII:88; 70 22.6'N, 147 38.3'W; 8.75m
Margaritas giganteus - 1
Buccinum angulosum - 1
Natica russa dead
Cylichna occulata - 1
Diaphana minuta - 4
Oenopota novajasemliensis - 4
Gn. sp. - 1
Liocyma fluctuosa - 4
Tridonta borealis - 1
Pandora glacialis - 1
Astarte montagui - 3
Portlandia arctica dead
Lyonsia arenosa dead
Axinopsida orbiculata - 1

88-6 B02:033; 5:VIII:88; 70 19.7'N, 147 39. 0'W; 7m
Polinices pallida dead
Diaphana minuta - 3
Oenopota novajasemliensis - 18
Oenopota sp. - 1
Tellina nuculoides - 35
Tridonta borealis dead
Pandora glacialis - 3
Macoma moesta alaskana - 1
Astarte montagui - i
Portlandia arctica - 1
Macoma crassula - 3
Lyonsia arenosa - 5

88-7 B02:035; 5:VIII:88; 70 20.5'N, 147 43.1'W; 7.5m
Polinices pallida - 2
Philine polaris - 1
Diaphana minuta - 1
Oenopota novajasemliensis - 4
Liocyma fluctuosa - 10
Tridonta borealis - 1
Pandora glacialis - 1
Crytodaria kurriana - 36
Astarte montagui - 8
Portlandia arctica - 25
Macoma crassula - 1

88-8 B02:037; 5:VIII:88; 70 20.8'N, 147 48.3'W; 5.5m
Diaphana minuta dead
Oenopota novajasemliensis - 5
Liocyma fluctuosa - 11
Tridonta borealis - 1
Crytodaria kurriana dead
Astarte montagui - 3
Portlandia arctica - 2

88-9 B02:038; 5:VIII:88; 70 20.8'N, 147 48.5'W; 5m

88-10 Bullen PT.: 8:IX:88; 70 10.8'N, 146 58.1'W; 2.5m
Amauropsis islandica - 1
Neptunea heros dead
Buccinum angulosum dead
Cylichna occulata - 5
Diaphana minuta - 24
Musculus discors dead
Liocyma fluctuosa - 2
Tridonta borealis dead
Crytodaria kurriana - 3
Yoldiella intermedia - 5
Boreacola vadosa _ 87

88-11 Bullen Pt. ; 9:VIII:88; 70 11.5'N, 146 58.6'W; 2.5m

88-12 B03:044; 9: VI II:88; 70 12. 0'N, 146 58.3'W; 5.5m
Cylichna occulata - 1
Diaphana minuta - 1
Oenopota novajasemliensis - 12
Odostomia albula - 7
Liocyma fluctuosa - 12
Tridents borealis - 5
Macoma moesta alaskana - 1
Astarte montagui - 4
Portlandia arctica - 9

88-13 B03:046; 9:VIII:88; 70 12.4'N, 147 03.0'W;6.0m
Natica russa - 4
Polinices pallida - 9 + egg case
Philine Polaris - 10
Cylichna occulata - 10
Diaphana minuta - 17
Oenopota novajasemliensis - 141
Odostomia● lbula - 32
Admete sp. #850 - 7
Liocyma fluctuosa - 46
Tridonta borealis - 64
Macoma moesta alaskana - 8
Astarte montagui - 65
Portlandia arctica - 20
Macoma crassula - 5
Lyonsia● renosa - 3
Axinopsida orbiculata - 2
Yoldiella intermedia - 2

88-14 B03:049; 9:VIII:88; 70 15.4'N, 147 06. 1'W;7.0m;Mud
Polinices pallida dead
Philine polaris - 3
Cylichna occulata - 1
Oenopota novajasemliensis - 13
Odostomia albula - 5
Odostomia castanea - 1
Retusa sp. #844 - 2
Liocyma fluctuosa - 10
Tridonta borealis - 9
Macoma calcarea - 1
Macoma moesta alaskana - 2
Astarte montagui - 25
Portlandia arctica - 9
Diplodonta aleutica - 1

88-15 9:VIII:88: 70 15.0'N, 146 57.7'W; 4m; Sand
Cylichna occulata - 3
Oenopota novajasemliensis - 2
Liocyma fluctuosa - 9
Astarte montagui - 1
Musculus corrugates dead
Boreacola vadosa - 4

88-16 B03:051; 9:VIII:88; 70 13.9'N, 146 53.0'W; 4.5m; S - M

Boreoscala greenlandica - 1
Oenopots simplex - 11
Polinices pallida - egg case
Philine polaris - 1
Cylichna occulata - 34
Diaphana minuta - 10
Oenopota roses - 1
Oenopota novajasemliensis - 4
Musculus niger dead
Liocyma fluctuosa - 234
Tridonta borealis - '3
Macoma calcarea - 6
Crytodaria kurriana - 9
Astarte montagui dead
Musculus corrugates - 17
Portlandia arctica - 3
Axinopsida orbiculata - 3

88-17 B03:058; 10:VIII:88; 70 16.9'N, 146 46.3'W; 10.0m; G

Liocyma fluctuosa - 4
Axinopsida orbiculata - 1

88-18 B03:059; 10:VIII:88; 70 15.8'N, 146 41.9'W; 7.0m; G

Oenopota novajasemliensis - 1

88-19 B03:068; 11:VIII:88; 70 12.3'N, 146 56.1'W; 6m; M - S

Margaritas giganteus - 1
Neptunea heros - 2
Velutina undata - 1
Oenopots simplex - 1
Polinices pallida - 1
Neptunea borealis dead
Oenopota roses - 1
Oenopota novajasemliensis - 31
Odostomia albula - 5

88-20 B03:069; 11:VIII:88; 70 12.5'N, 146 59.6'W; 5.5m;

88-21 B03:071; 11:VIII:88; 70 12.3'N, 147 01.4'W; 5.5m;

88-22 B03:072; 11:VIII:88; 70 12.6'N, 146 59.7'W; 5.5m; Mud

Polinices pallida - 1
Philine Polaris - 1
Diaphana minuta - 2
Oenopota novajasemliensis - 49
Musculus discors - 2
Liocyma fluctuosa - 22
Tridonta borealis - 4
Pandora glacialis - 3
Macoma moesta alaskana - 2
Astarte montagui - 4
Musculus corrugates - 1
Portlandia arctica - 2
Macoma crassula - 1

88-23 B03:073; 11: VIII:88; 70 12.6'N, 146 59.7'W; 5.5m; Mud
Cylichna occulata - 7
Diaphana minuta - 3
Liocyma fluctuosa - 1
Tridonta borealis - 1
Portlandia arctica - 2
Axinopsida orbiculata - 1
Yoldiella intermedia - 155

88-24 17:VIII:88; 70 27.4'N, 148 34.7'W; 9m; Mud
Philine Polaris - 1
Cylichna occulata - 2
Diaphana minuta - 2
Oenopota novajasemliensis - 13
Odostomia albula - 1
Liocyma fluctuosa - 11
Macoma calcarea - 5
Crytodaria kurriana - 1
Macoma moesta alaskana - 2
Astarte montagui - 2
Portlandia arctica - 13
Axinopsida orbiculata - 45

88-25 18:VIII:88; 70 11.7'N, 146 13.0'W; 1.6m; Mud
Amauropsis islandica - 1
Cylichna occulata - 1
Diaphana minuta - 2
Crytodaria kurriana dead
Portlandia arctica - 7

88-26 C02:075; 18:VIII:88; 70 03.5'N, 145 18.4'W;8.0m; Sand
Margaritas giganteus - 2
Oenopots simplex - 2
Philine Polaris - 2
Cylichna occulata - 4
Diaphana minuta - 6
Oenopota novajasemliensis - 2
Liocyma fluctuosa - 86
Tridonta borealis - 1
Musculus corrugates - 10
Mya pseudoarenaria - 3
Portlandia arctica - 5
Macoma crassula - 8
Lyonsia arenosa - 1
Axinopsida orbiculata - 28
Boreacola vadosa - 6
Pisidium idahoense dead (freshwater)

88-27 19:VIII:88; 69 58.6'N, 144 50.8'W;2.6m;Mud
Polinices pallida egg case
Cylichna occulata - 1
Liocyma fluctuosa - 1
Crytodaria kurriana - 35
Yoldiella intermedia - 24

88-28 Simpson 20:VIII:88;69 58.6'N, 144 52'W; 3.1m; Mud
Cylichna occulata - 39
Diaphana minuta - 27
Portlandia arctica - 2

88-29 C03:079; 21:VIII:88; 69 59.6'N, 144 32.0'W;5.5m; Mud
Diaphana minuta - 3
Oenopota novajasemliensis - 6
Liocyma fluctuosa - 8
Macoma moesta alaskana - 13
Mya pseudoarenaria - 1
Portlandia arctica - 10
Axinopsida orbiculata - 7
Yoldiella intermedia - 2

88-30 C03:081; 21:VIII:88; 63 58.6'N, 144 36.3'W; 5.5m; Mud
Cylichna occulata - 1
Diaphana minuta - 2
Oenopota novajasemliensis - 4
Liocyma fluctuosa - 12
Tridonta borealis - 1
Macoma moesta alaskana - 8
Mya pseudoarenaria - 1
Portlandia arctica - 1
Macoma crassula - 1
Axinopsida orbiculata - 1

88-31 C03:083; 21:VIII:88; 69 59.7'N, 144 33.6'W; 7.0m; Mud
Polinices pallida egg ease
Diaphana minuta - 3
Oenopota novajasemliensis - 23
Odostomia albula - 3
Liocyma fluctuosa - 66
Tridonta borealis - 11
Pandora glacialis - 2
Macoma moesta alaskana - 6
Mya pseudoarenaria - 9
Portlandia arctica - 142
Macoma crassula - 2
Lyonsia arenosa - 21
Axinopsida orbiculata - 9

88-32 C03:085:21:VIII:88; 70 01.5'N, 144 35.3'W;10.0m; Mud

Natica russa - 1
Polinices pallida - 1
Philine polaris - 2
Diaphana minuta - 2
Oenopota novajasemliensis - 23
Odostomia albula - 1
Liocyma fluctuosa - 13
Pandora glacialis - 1
Macoma calcarea - 1
Astarte montagui - 6
Musculus corrugates - 3
Mya pseudoarenaria - 3
Portlandia arctica - 4
Macoma crassula - 1
Axinopsida orbiculata - 4

88-33 C03:088; 21:VIII:88; 70 00.7'N, 144 46.3'W; 10.0m; Mud

Colus dautzenbergi - 1
Oenopots simplex - 2
Polinices pallida - 3
Philine Polaris - 26
Cylichna occulata - 1
Diaphana minuta - 9
Oenopota novajasemliensis - 118
Odostomia albula - 1
Oenopota sp. #843 dead
Admete sp. #850 - 9
Liocyma fluctuosa - 39
Nucula tenius - 1
Tridonta borealis - 13
Pandora glacialis - 15
Macoma moesta alaskana - 19
Astarte montagui - 54
Musculus corrugates - 27
Mya pseudoarenaria - 13
Portlandia arctica - 12
Macoma crassula - 8
Lyonsia arenosa - 18
Axinopsida orbiculata - 2
Yoldiella intermedia - 1

88-34 C03:090; 21:VIII:88; 69 59.3'N, 144 46. 8'W; 8.5m; Mud

Polinices pallida dead
Philine polaris dead
Diaphana minuta - 2
Oenopota novajasemliensis - 16
Oenopota sp. #679 - 1
Odostomia albula - 1
Liocyma fluctuosa - 34
Nucula tenius dead
Tridonta borealis - 12
Pandora glacialis - 1
Macoma calcarea - 4
Macoma moesta alaskana - 9
Astarte montagui - 27
Mya pseudoarenaria dead
Portlandia arctica - 5
Macoma crassula - 11
Axinopsida orbiculata - 1
Thyasira equalis dead

68-35 C03:092; 22:VIII:88; 70 00.9'N, 144 03.2'W; 8.0m; Mud

Diaphana minuta - 1
Oenopota novajasemliensis - 1
Liocyma fluctuosa - 32
Tridonta borealis - 2
Portlandia arctica - 24
Axinopsida orbiculata - 5

88-36 C03:094; 22:VIII:88; 70 00.6'N, 147 49.7'W; 8.5m; Mud

Oenopots simplex - 2
Polinices pallida dead
Philine Polaris - 1
Diaphana minuta - 7
Oenopota novajasemliensis - 27
Odostomia albula - 2
Musculus discors - 2
Hiatella arctica - 1
Liocyma fluctuosa - 54
Tridonta borealis - 6
Pandora glacialis - 4
Macoma moesta alaskana - 21
Musculus corrugatus - 1
Mya pseudoarenaria - 1
Portlandia arctica - 21
Macoma crassula - 4
Lyonsia arenosa - 22
Axinopsida orbiculata - 1

88-37 C01:095; 22: VI II:88; 70 02.4'N, 145 17.4' W; 6m; Gravel
Velutina velutina - 1
Cylichna occulata - 2
Diaphana minuta - 7
Oenopota novajasemliensis - 1
Musculus discors - 27
Liocyma fluctuosa - 17
Pandora glacialis - 3
Astarte montagui - 3
Axinopsida orbiculata - 2
Boreacola vadosa - 3

88-38 C01:098; 22:VIII:88; 70 06.0'N, 145 33.8*W; 8.5m; Sand
Cylichna occulata - 27
Liocyma fluctuosa - 32
Macoma calcarea - 1
Macoma moesta alaskana - 1
Mya pseudoarenaria - 2
Portlandia arctica - 2
Axinopsida orbiculata - 24

88-39 Thetis 26:VIII:88; 70 03.1'N, 150 08.9'W; 1.8m; Mud
Crytodaria kurriana - 9

88-45 A03:101; 27:VIII:88; 70 34.0'N, 150 18.1'W; 7.0m; Mud
Cylichna occulata - 2
Liocyma fluctuosa - 8
Pandora glacialis - 1

88-41 A03:102; 28:VIII:88; 70 33.2'N, 150 11.5'W; 0.6-1.8m; G
Amauropsis islandica dead

88-42 Thetis 28:VIII:88; 70 32.0'N, 150 12.9'W; 4m; Mud
Crytodaria kurriana - 4
Portlandia arctica - 19 "

88-43 Thetis 28:VIII:88; 70 35.1'N, 150 15.1'W; 10m; Mud
Diaphana minuta - 2
Oenopota novajasemliensis - 9
Oenopota sp. #843 dead
Liocyma fluctuosa - 6
Tridonta borealis dead
Macoma calcarea - 1
Portlandia arctica - 56
Lyonsia arenosa - 11
Axinopsida orbiculata - 20
Yoldiella intermedia - 3

88-44 Oliktok 2:IX:88; 70 31.2'N, 149 52.8'W; 2.5m, Mud
Polinices pallida - 1
Crytodaria kurriana - 1
Yoldiella intermedia - 48

88-45 A03:114; 3:I X:88; 70 33.4'N, 150 18.0'W; 5.5m; Mud
Crytodaria kurriana - 2
Portlandia ● retica - 4
Yoldiella intermedia - 1

88-46 A03:119; 3:IX:88; 70 32.8'N, 150 14.0'W; 5.5m; Mud
Yoldiella intermedia - 4

88-47 Pingok 8:IX:88; 70 34.8'N, 149 36.1'W; 10.5m; *Mud*
Portlandia arctica - 3
Axinopsida orbiculata - 2

88-48 Simpson C. ; 18:VIII:88; 69 58.6'N, 144 50.7'W; beach drift

88-49 Behind Stump Is. ; 70 25'N, 148 37'W; 1.2-1.8m; 16:Viii:88
Cylichna occulata dead
Oenopota novajasemliensis - 1
Valvata sincera dead {freshwater)
Liocyma fluctuosa - 1
Crytodaria kurriana - dead
Portlandia arctica - 1

Appendix B
Fish Data: Meristics and Counts

1. Specimen 1266
2. Area Beaufort Sea*
3. Species Arctic Cisco
4. Date 4/8/88
5. * 70° 13.1' N; 147° 00.1'W
6. Sex/Condition F1
7. Scale Card
8. Scale#
9. Weight (g) 600
10. Fork Length 375 mm
11. Standard Length 343 mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length
15, Body Length
16. Head Length 69.0 mm
17. Maxillary Len. ‹0 „ 3 ‹ m
18. Maxillary Depth
19. Lower Jaw Len. 27.6 mm
20. Eye Diameter 13 mm
21, Obit Length 15 mm
22. Snout-Nostril 16,5 mm
23, Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 161.6 mm
27. Snout-Adipose 274 mm
28, Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 272 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Pseudobranchia ++
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 25.1 mm
42. Interorbital Width 17.9 mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 79.2 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 49.6 mm
55. Pelvic Length 49.3 mm
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Rays 12
59. Caudal Rays (forked) 16
60. Pectoral Rays 18
61. Pelvic Rays 12
62. Anal Rays 13
63. InOrb Shape - Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 96 = 93+3
71. Pores, Std.Len.
72. Scales, Lateral Line 99
73. Scales (1st power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal 13
76. Scales, Ventral 14
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 8/8
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 47 = 17+1+29
82. Gill Rakers, 2nd Arch 45
83. Gill Raker Len. 8.9 mm
84. Gill Raker Space
85. Pyloric Caeca
86. Vertebra 75
87. Physical Condition
88. Gill Slit 4th- 14.0 mm
89. Vomer Width O
90. Palatine Length n
91.
92. Food
93.
94. Max Extend to mid eye
95.

1. Specimen 1267	40. Dorsal Fin Depth ____	70. Pores, Lateral Line 146 = 140+6
2. Area Beaufort Sea*	41. Caudal Peduncle Depth 25.6 mm	71. Pores, Std.Len. ____
3. Species Arctic char	42. Interorbital Width 23.3 mm	72. Scales, Lateral Line ____
4. Date 4/8/88	43. Mid-eye Width ____	73. Scales (1st power above L.L.) ____
5. * 70° 13.1'N;147° 00.1'W	44. Occiput Width ____	74. Scales,Occip. ____
6. Sex/Condition M1	45. Body Width 79.2 mm	75. Scales, Dorsal ____
7. Scale Card ____	46. Caudal Peduncle Width ____	76. Scales, Ventral ____
8. Scale# ____	47. Circumference ____	77. Scales, Supra-pelvic ____
9. Weight (g) ____	48. Dorsal Fin Length ____	78. Scales around Caudal Peduncle ____
10. Fork Length 375 mm	49. Dorsal Height (anterior/posterior) ____	79. Branchiostegals 11/11
11. Standard Length 343 mm	50. Adipose Base Length ____	80. Pores, Lower Jaw ____
12. Mid-Eye Length ____	51. Adipose Height ____	81. Gill Rakers 1st Arch 22
13. Rear Obit Len. ____	52. Adipose Length ____	82. Gill Rakers, 2nd Arch 22 = 10+1+11
14. Total Length 406 mm	53. Caudal Fin Length (minimum/maximum) ____	83. Gill Raker Len, 6.8 mm
15. Body Length ____	54. Pectoral Length 42.2 mm	84. Gill Raker Space ____
16. Head Length 69.0 mm	55. Pelvic Length 39.1 mm	85. Pyloric Caeca 34
17. Maxillary Len. 25.2 mm	56. Anal Fin Length ____	86. Vertebra 69
18. Maxillary Depth ____	57. Anal Height (anterior/posterior) ____	87. Physical Condition
19. Lower Jaw Len. 36.2 mm	58. Dorsal Fin Rays 15	88. Depth Collected-6m
20. Eye Diameter ____	59. Caudal Rays (forked) 17	89. Gill Slit 4th - 16.4 mm
21. Orbit Length 14.8 mm	60. Pectoral Rays ____	90. Vomer Width - 4.3 mm
22. Snout-Nostril 15.8 mm	61. Pelvic Rays 11	91. Palatine Length 11.3 mm
23. Snout-Maxillary ____	62. Anal Rays 14	92. Food ____
24. Snout-Anterior Orbit Length ____	63. InOrbit Shape - Convex	93. ____
25. Snout-Occip ____	64. ____	94. Max. Extends - Rear Orbit
26. Snout-Dorsal 141.4 mm	65. ____	95. Pseudo branchia - ++
27. Snout-Adipose 274 mm	66. Liver Weight ____	
28. Snout-Pectoral ____	67. Gonad Weight ____	
29. Snout-Pelvic ____	68. Egg Number ____	
30. Snout-Anal 244 mm	69. Egg Diameter ____	
31. Dorsal-Adipose ____		
32. Pectoral-Pelvic ____		
33. Pelvic-Anal ____		
34. Pelvic Caudal ____		
35. Dorsal Caudal Length ____		
36. Ventral Caudal Length ____		
37. Pink Spot Dia. - 3.5 mm		
38. Mid-Eye Depth ____		
39. Occiput Depth ____		

1. Specimen 1268
2. Area 1-M depth, Bullen Pt
3. Species Arctic char
4. Date 10/08/88
5.
6. Sex/Condition F3
7. Scale Card
8. Scale#
9. Weight (g) 1000
10. Fork Length 558 mm
11. Standard Length 504 mm
12. Mid-Eye Length
13. Rear Orbit Len.
14. Total Length 587 mm
15. Body Length
16. Head Length 103.3 mm
17, Maxillary Len. 43.0 mm
18, Maxillary Depth
19. Lower Jaw Len. 64.9 mm
20. Eye Diameter 17.3 mm
21. Orbit Length 18.9 mm
22. Snout-Nostril 28.3 mm
23. Snout-Maxillary
24, Snout-Anterior Orbit Length
25. Snout-Occip
26. Snout-Dorsal 227 mm
27, Snout-Adipose 419 mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 368 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34, Pelvic Caudal
35. Dorsal Caudal Length
36. Ventral Caudal Length
37. Pink Spot Dia. 5.0 mm-
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 36.7 mm
42. Interorbital Width 34.4 mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 101 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 70.8 mm
55. pelvic Length 61.1 mm
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Rays 12
59. Caudal Rays (forked) 17
60. Pectoral Rays 15
61. Pelvic Rays 10
62. Anal Rays 11
63. *Pseudobranchia ± 25*
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 136 = 128+8
71. Pores, Std.Len.
72. Scales, Lateral Line
73. Scales (1st power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal
76. Scales, Ventral
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 11/11
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 21 = 8+1+12
82. Gill Rakers, 2nd Arch 21
83. Gill Raker Len. 9 mm
84. Gill Raker Space
85. Pyloric Caeca 35
86. Vertebra
87. Physical Condition
88. Pseudobranchia - ± 25
89. Gill Slit 4th -18.3 mm
90. Vomer Width - 6.5 mm
91. Palatine Width-3.0 mm
92. Food
93. Palatine Teeth - 12
94. Paltine Length - 19.4 mm
95. *Max. Extends - Post Orbit*

1. Specimen 1269
2. Area Button Pt.
3. Species Arctic Cisco
4. Date 10 /August/ 1988

6. Sex/Condition F3
7. Scale Card
8. Scale#
9. Weight (g) 1000
10. Fork Length
11. Standard Length 396 mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 469 mm
15. Body Length
16. I-lead Length 79.3 m
17. Maxillary Len. 21.9 mm
18. Maxillary Depth
19. Lower Jaw Len. 31.0 mm
20. Eye Diameter 12.9 mm
21. Obit Length 17.8 mm
22. Snout-Nostril 15.5 mm
23. Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 193.7 mm
27. Snout-Adipose 331 mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 308 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Pseudobranchia ++ very short
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 29.7 mm
42. Interorbital Width 19.5 mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 95 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 57.6 mm
55. Pelvic Length 56.0
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Raysf~]j-
59. Caudal Rays (forked) 17
60. Pectoral Rays 16
61. Pelvic Rays 12
62. Anal Rays (2) 13
63. InOrbit Shape - Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 89 + 3
71. Pores, Std.Len.
72. Scales, Lateral Line
73. Scales (1st power above L.L.)
74. Scales, Occip.
75. Scales, Dorsal "
76. Scales, Ventral "
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 9/9
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 16+1+28=45
82. Gill Rakers, 2nd Arch 18+1+27=46
83. Gill Raker Len. 11.4 mm
84. Gill Raker Space
85. Pyloric Caeca ??
86. Vertebra 35+5+23=63
87, Physical Condition
88. Gill Slit 4th - 15.8 mm
89. Vomer Width " 0
90. Palatine Len - 0
91. Depth Collected - 2m
92. Food

94. Max Extends - mid eye
95.

1. Specimen 1670
2. Area Bullen Point
3. Species Least Cisco
4. Date 10/08/88
5. Depth Captured
6. Sex/Condition F3
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 340 mm
11. Standard Length 314 mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 383 mm
15. Body Length
16. Head Length 63.2 mm
17. Maxillary Len. 19.5 mm
18. Maxillary Depth
19. Lower Jaw Len. 2s.L-
20. Eye Diameter 13.3 mm
21. Obit Length 17.4 mm
22. Snout-Nostril /~.7-
23. Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 137.8 mm
27. Snout-Adipose 268 mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 237.7 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Max. Extends - mideye
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 24.6 mm
42. Interorbital Width 14.2 mm
43. Mid-eye Width
44. Occiput Width
45. Body Width ?4 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 56.8 mm
55. Pelvic Length 54.8 mm
56. Anal Fin Length
57. Anal Height {anterior/ posterior)
58. Dorsal Fin Rays 14+2+12
59. Caudal Rays (forked) 17
60. Pectoral Rays 16
61. Pelvic Rays 13
62. Anal Rays 2+15 = 17
63. In Orb Shape - Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 84+3c
71. Pores, Std.Len.
72. Scales, Lateral Line
73. Scales (1st power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal 10
76. Scales, Ventral 10
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 8/e
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 15+1+32 = 48
82. Gill Rakers, 2nd Arch 17+1+30 = 48
83. Gill Raker Len. 10.0 mm
84. Gill Raker Space
85. Pyloric Caeca 90
86. Vertebra 34+5+23 . 62
87. Physical Condition
88. Gill Slit 4th . 12.9
89. Vomer Width = 0
90. Palatine Len . 0
91.
92. Food
93.
94. Pseudobranchia ± 69
95.

1. Specimen 1671
2. Area Bullen Point
3. Species Broad Whitefish
4. Date 10 108 1 88
5. Depth Captured 2-m
6. Sex/Condition F1
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 367 mm
11. Standard Length 340 mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 409 mm
15. Body Length
16. Head Length 64.5 mm
17. Maxillary Len. 13.9mm X7.4
18. Maxillary Depth
19. Lower Jaw Len. 20.6mm
20. Eye Diameter 11. 7mm
21. Obit Length 15.4 mm
22. Snout-Nostril 1.5.5mm
23. Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 153 mm
27. Snout-Adipose 283 mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 260 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Max Extends · Front Orbit
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 24.6mm
42. Interorbital Width 20.5mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 79 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 58.3mm
55. Pelvic Length 56.7 mm
56. Anal Fin Length
57. Anal Height "(anterior/ posterior)
58. Dorsal Fin Rays 3+12=15
59. Caudal Rays (forked) 17
60. Pectoral Rays 16
61. Pelvic Rays 12
62. Anal Rays 3+14 = 17
63. In Orbit Shape · Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 84+2C
71. Pores, Std.Len.
72. Scales, Lateral Line 86
73. Scales (1st power above L.L.)
74. Scales, Occip.
75. Scales, Dorsal 11
76. Scales, Ventral 9
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 9/8
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 7+1+13 = 21
82. Gill Rakers, 2nd Arch 6+1+10 = 17
83. Gill Raker Len. 4.1 mm
84. Gill Raker Space
85. Pyloric Caeca 149
86. Vertebra
87. Physical Condition
88. Gill Slit 4th - 14.0
89. [illegible] Width 0
90.
91.
92. Food
93.
94. Pseudobranchia +
95.

1. Specimen 1672
2. Area Bullen Point
3. Species Arctic Cisco
4. Date 10/08/88
5. Depth Cooked
6. Sex/Condition F2
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 412 mm
11. Standard Length 378 mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 448 mm
15. Body Length
16. Head Length 70.7 mm
17. Maxillary Len. 19.5 mm
18. Maxillary Depth
19. Lower Jaw Len. 31.2 mm
20. Eye Diameter 11.5 mm
21. Obit Length 16.1 mm
22. Snout-Nostril 14.5 mm
23. Snout-Maxillary
24, Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 174 mm
27, Snout-Adipose 324 mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 303 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Max Extends - ton Pupil
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 26.7 mm
42. Interorbital Width ~g,<-
43. Mid-eyeWidth
44. Occiput Width
45. Body Width 99 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 57.3 mm
55. Pelvic Length 48.7 mm
56. Anal Fin Length
57. Anal Height (anterior/posterior)
58. Dorsal Fin Rays 3+13=16
59. Caudal Rays (forked) 17
60. Pectoral Rays 16
61. Pelvic Rays 12
62. Anal Rays 2+13=15
63. In Orbit Shape - Convex
64. Pseudobranchia —
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line
71. Pores, Std.Len.
72. Scales, Lateral Line 98
73. Scales (1st power above L.L.) 93+0C
74. Scales,Occip.
75. Scales, Dorsal 11
76. Scales, Ventral 10
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 8/8
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 15+1+27=43
82. Gill Rakers, 2nd Arch 18+1+28 = 47
83. Gill Raker Len. 9.8 mm
84. Gill Raker Space
85. Pyloric Caeca 147
86. Vertebra
87. Physical Condition
88. Gill Slit 4th - 15.9
89. Vomer Width - 0
90. Palatine Length - 0
91.
92. Food
93.
94.
95.

1. Specimen 1273
2. Area Prudhoe Bay
3. Species Arctic Char
4. Date 8/23/88
5.
6. Sex/Condition F15
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 580 mm
11. Standard Length 523 mm
12. Mid-Eye Length 550mm
13. Rear Obit Len. 540 mm
14. Total Length 607 mm
15. Body Length 541 mm
16. Head Length 105 mm
17. Maxillary Len. 47.9 mm
18. Maxillary Depth 9.2 mm
19. Lower Jaw Len. 69 mm
20. Eye Diameter 15 mm
21. Obit Length 21.1 mm
22, Snout-Nostril 20.5 mm
23. Snout-Maxillary 58.4 mm
24. Snout-Anterior Obit Length 29.8 mm
25. Snout-Occip 65 mm
26, Snout-Dorsal 218 mm
27. Snout-Adipose 437 mm
28. Snout-Pectoral 100 mm
29. Snout-Pelvic 254 mm
30. Snout-Anal 386 mm
31. Dorsal-Adipose 211.5 mm
32. Pectoral-pelvic 165.6 mm
33. Pelvic-Anal 137.7 mm
34. Pelvic Caudal 268 mm
35. Dorsal Caudal Length 44.3 mm
36. Vental Caudal Length 57.2 mm
37. Caudal Peduncle Len 96.5
38. Mid-Eye Depth 49.3 mm
39. Occiput Depth 67.3 mm
40. Dorsal Fin Depth 125 mm
41. Caudal Peduncle Depth 39.2 mm
42. Interorbital Width 38.0 mm
43, Mid-eye Width 44.3 mm
44. Occiput Width 53.1 mm
45. Body Width 70.2 mm
46. Caudal Peduncle Width 30.5 mm
47. Circumference 123 mm
48. Dorsal Fin Length 68.0 mm
49. Dorsal Height (anterior/posterior) 61-2/25//3
50. Adipose Base Length 5.7 mm
51. Adipose Height 6.5 mm
52. Adipose Length 17.5 mm
53. Caudal Fin Length (minimum/maximum) 57.2/78.5
54. Pectoral Length 70.2 mm
55. Pelvic Length 64,6 mm
56. Anal Fin Length 48.9 mm
57. Anal Height (anterior/posterior) 61.5/23.8
58. Dorsal Fin Rays 3+12=15
59. Caudal Rays (forked) 17
60. Pectoral Rays 14
61. Pelvic Rays 9
62. Anal Rays 2+11=13
63. Spot Dig. 3-6.3 mm
64. Slit behind 4th gill 19.3 mm
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 143
71. Pores, Std.Len. 135 +8c
72. Scales, Lateral Line
73. Scales (1st power above L.L.)
74. Scales, Occip.
75. Scales, Dorsal 48
76. Scales, Ventral 48
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 11/11
80. Pores, Lower Jaw 71
81. Gill Rakers 1st Arch 22 = 10+1+11
82. Gill Rakers, 2nd Arch 22 = 9+1+12
83. Gill Raker Len. 10.8 mm
84. Gill Raker Space 1.7 mm
85. Pyloric Caeca 35
86. Vertebra 35+5+28= 68
87. Physical Condition 2
88. Vomer W 5.2 mm
89. Palatine L 21.6 mm
90. Vomer Teeth 5
91. Palatine Teeth 18
92. Food 1 Arctic Cod
93. Tongue Teeth 8/10
94.
95.

1. Specimen 1274
2. Area Prudhoe Bay
3. Species Arctic Char
4. Date 8/23/88
5.
6. Sex/Condition F 15
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 533 mm
11. Standard Length 483 mm
12. Mid-Eye Length 515 mm
13. Rear Obit Len. 503 mm
14. Total Length 563 mm
15. Body Length 504 mm
16. Head Length 99.9 mm
17. Maxillary Len. 41.5 mm
18. Maxillary Depth 8.7 mm
19. Lower Jaw Len. 62.9 mm
20. Eye Diameter 14.5 mm
21. Obit Length 19.7 mm
22. Snout-Nostril 18.7 mm
23. Snout-Maxillary 51.7 mm
24. Snout-Anterior Obit Length 25.4 mm
25. Snout-Occip 59.2 mm
26. Snout-Dorsal 208 mm
27. Snout-Adipose 396 mm
28. Snout-Pectoral 99.0 mm
29. Snout-Pelvic 255 mm
30. Snout-Anal 366 mm
31. Dorsal-Adipose 125.4 mm
32. Pectoral-Pelvic 152 mm
33. Pelvic-Anal 118.5 mm
34. Pelvic Caudal 250.5 mm
35. Dorsal Caudal Length 46.3 mm
36. Vental Caudal Length 62.6 mm
37. Caudal Peduncle Len 94.8
38. Mid-Eye Depth 49.0 mm
39. Occiput Depth 58.5 mm
40. Dorsal Fin Depth 115 mm
41. Caudal Peduncle Depth 36.7 mm
42. Interorbital Width 33.3 mm
43. Mid-eye Width 41.0 mm
44. Occiput Width 50.7 mm
45. Body Width 63.7 mm
46. Caudal Peduncle Width 22.5 mm
47. Circumference 106 mm
48. Dorsal Fin Length 56.3 mm
49. Dorsal Height (anterior/ posterior) 54.7/21.5
50. Adipose Base Length 5.9 mm
51. Adipose Height 9.0 mm
52. Adipose Length 22.5 mm
53. Caudal Fin Length (minimum/maximum) 50/77.5
54. Pectoral Length 73.4 mm
55. Pelvic Length 64.2 mm
56. Anal Fin Length 42.3 mm
57. Anal Height (anterior/ posterior) 56.0/19.5
58. Dorsal Fin Rays 15 : 3+12
59. Caudal 'Rays (forked) 17
60. Pectoral Rays 14
61. Pelvic Rays 9
62. Anal Rays 3+10 = 13
63. Vomer W 6.0mm
64. Vomer Teeth 8
65. ~~Pink Spot Dia.~~ 5.5 mm
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter 1.8 mm
70. Pores, Lateral Line 137
71. Pores, Std.Len. 132 mm
72. Scales, Lateral Line
73. Scales (1st power above L.L.)
74. Scales, Occip.
75. Scales, Dorsal
76. Scales, Ventral
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 12/12
80. Pores, Lower Jaw 6/7
81. Gill Rakers 1st Arch 24 = 1+1+12
82. Gill Rakers, 2nd Arch 26 = 1+1+14
83. Gill Raker Len. 9.2 mm
84. Gill Raker Space 2.4 mm
85. Pyloric Caeca 33
86. Vertebra 33+6+28 = 67
87. Physical Condition 2
88. Palatine Length 20.6 mm
89. Palatine Teeth 21
90. Slit behind 4th sill 19 mm
91.
92. Food
93.
94.
95.

1. Specimen 1275 a
2. Area Prudhoe Bay
3. Species Arctic Char
4. Date 24/08/88
5.
6. Sex/Condition M 15
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 579 mm
11. Standard Length 529 mm
12. Mid-Eye Length 548 mm
13. Rear Obit Len. 537 mm
14. Total Length 615 mm
15, Body Length 555 mm
16. Head Length 119.4 mm
17. Maxillary Len. 53.5 mm
18. Maxillary Depth 7.2 mm
19. Lower Jaw Len. 85.5 mm
20, Eye Diameter 13.3 mm
21. Obit Length 22.4 mm
22. Snout-Nostril 28.1 mm
23. Snout-Maxillary 73.0 mm
24. Snout-Anterior Obit Length 36.4 mm
25. Snout-Occip 79.8 mm
26. Snout-Dorsal 242 mm
27. Snout-Adipose 436 mm
28. Snout-Pectoral 117.0 mm
29. Snout-Pelvic 276 mm
30. Snout-Anal 399 mm
31. Dorsal-Adipose 204.8 mm
32. Pectoral-Pelvic 159.1 mm
33. Pelvic-Anal 124.5 mm
34, Pelvic Caudal 262.7 mm
35. Dorsal Caudal Length 52.8 mm
36. Vental Caudal Length 61.3 mm
37. Caudal Peduncle Len 95.6
38. Mid-Eye Depth 50.2 mm
39. Occiput Depth 72.2 mm

40. Dorsal Fin Depth 134 mm
41. Caudal Peduncle Depth 43.7 mm
42. Interorbital Width 38.7 mm
43. Mid-eye Width 46.5 mm
44. Occiput Width 55.7 mm
45. Body Width 72 mm
46. Caudal Peduncle Width 26.1 mm
47. Circumference
48. Dorsal Fin Length 63.5 mm
49. Dorsal Height (anterior/posterior) 61.0/29.8
50, Adipose Base Length 11.2 mm
51. Adipose Height 9.4 mm
52. Adipose Length 24.7 mm
53. Caudal Fin Length (minimum/maximum) 52/91.3
54. Pectoral Length 82.8 mm
55. Pelvic Length 74.8mm
56. Anal Fin Length 45.6 mm
57. Anal Height (anterior/posterior) 63.5/24.8
58. Dorsal Fin Rays 14=3+11
59. Caudal Rays (forked) 17
60. Pectoral Rays 14
61. Pelvic Rays 10
62. Anal Rays 13
63. Vomar w/teeth 8.4/7.0
64. Palatine w/teeth 21.7/14
65. Tongue Teeth 5/7
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter

70. Pores, Lateral Line 137
71. Pores, Std.Len. 133
72. Scales, Lateral Line
73. Scales (1st power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal
76. Scales, Ventral
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 14/12
80. Pores, Lower Jaw 7/7
81. Gill Rakers 1st Arch 23 = 9+1+13
82. Gill Rakers, 2nd Arch 23 = 10+1+12
83. Gill Raker Len. 10.0 mm
84. Gill Raker Space 3.1 mm
85. Pyloric Caeca 31 mm
86. Vertebra 67
87. Physical Condition 2
88. Pink Spot Dia. 4.8mm
89. Slit Behind 4th gill 22.8mm
90.
91.
92. Food 9 Arctic cod
93. 1 Least Cisco
94.
95.

1. Specimen 1275 b
2. Area Thetis Island
3. Species Furhorn Sculpin
4. Date 27 /08/88
5. Depth Cp.]-M
6. Sex/Condition F3
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 191 mm
11. Standard Length 162 mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 191 mm
15. Body Length .
16. Head Length 57.3 mm
17. Maxillary Len. 23.9 mm
18. Maxillary Depth
19. Lower Jaw Len. 27.4 mm
20, Eye Diameter 8.6 mm
21, Obit Length 12.0 mm
22, Snout-Nostril
23. Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 58.3 mm
27, Snout-Adipose
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 104.7 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Pre D 2nd L 100.9 mm
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 6.5 mm
42. Interorbital Width 7.0 mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 38 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 43.8 mm
55. Pelvic Length 27.4 mm
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Rays VIII+13 (1st 3 Pectinate)
59. Caudal Rays (forked) 7+7+8
60. Pectoral Rays
61. Pelvic Rays I 3
62. Anal Rays / 5
63. In Orbit Shape - Concave
64. Max Extends Past Orbit
65. D interspace 6.6 mm
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 33
71. Pores, Std.Len.
72. Scales, Lateral Line
73. Scales (lst power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal Σ 47
76. Scales, Ventral Σ 27
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 2+4 = 6/6
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 1+0+6 = 7
82. Gill Rakers, 2nd Arch 0+0+6 = 6
83. Gill Raker Len. Spiny nub
84. Gill Raker Space
85. Pyloric Caeca 10
86. Vertebra 12+2+28 = 42
87. Physical Condition
88. Gill Slit 4th . Pore
89. Pseudobranchia 23
90. D. Spine Ray J 26.2 ± 5.3
91. Lateral Scales +
92. Food
93. Branchio memb. - Freefold
94. LL Canal - PoresFade under
95. tip of D
96. Vomer Width - 4.8 m
97. Palatine Length - 0
98. Coloration - Orange, Br. lower
99. eggs - purple

1. Specimen 1278
2. Area Oliktok Point
3. Species Rainbow Smelt
4. Date 04/09/88
5. ______
6. Sex/Condition ______
7. Scale Card ______
8. Scale# ______
9, Weight (g) ______
10. Fork Length ______
11. Standard Length 28 mm
12. Mid-Eye Length ______
13. Rear Obit Len. ______
14. Total Length skeleton only
15. Body Length ______
16. Head Length ______
17. Maxillary Len. 22 mm
18. Maxillary Depth ______
19. Lower Jaw Len. 29.4 mm
20. Eye Diameter ______
21. Obit Length 13.0 mm
22. Snout-Nostril ______
23. Snout-Maxillary ______
24. Snout-Anterior Obit Length ______
25. Snout-Occip ______
26. Snout-Dorsal ______
27. Snout-Adipose ______
28. Snout-Pectoral ______
29. Snout-Pelvic ______
30. Snout-Anal ______
31. Dorsal-Adipose ______
32. Pectoral-Pelvic ______
33. Pelvic-Anal ______
34. Pelvic Caudal ______
35. Dorsal Caudal Length ______
36. Ventral Caudal Length ______
37. ______
38. Mid-Eye Depth ______
39. Occiput Depth ______
40. Dorsal Fin Depth ______
41. Caudal Peduncle Depth ______
42. Interorbital Width 9.9 mm
43. Mid-eye Width ______
44. Occiput Width ______
45. Body Width ______
46. Caudal Peduncle Width ______
47. Circumference ______
48. Dorsal Fin Length ______
49. Dorsal Height [anterior/ posterior) ______
50. Adipose Base Length ______
51. Adipose Height ______
52. Adipose Length ______
53. Caudal Fin Length {minimum/maximum) ______
54. Pectoral Length ______
55. Pelvic Length ______
56. Anal Fin Length ______
57. Anal Height (anterior/ posterior) ______
58. Dorsal Fin Rays 11
59. Caudal Rays (forked) ______
60. Pectoral Rays ______
61. Pelvic Rays ______
62. Anal Rays ______
63. . ______
64. ______
65. ______
66. Liver Weight ______
67. Gonad Weight ______
68. Egg Number ______
69. Egg Diameter ______
70. Pores, Lateral Line ______
71. Pores, Std.Len. ______
72. Scales, Lateral Line ______
73. Scales (1st power above L.L.)
74. Scales,Occip. ______
75. Scales, Dorsal ______
76. Scales, Ventral ______
77. Scales, Supra-pelvic ______
78. Scales around Caudal Peduncle ______
79. Branchiostegals ______
80. Pores, Lower Jaw ______
81. Gill Rakers 1st Arch ______
82. Gill Rakers, 2nd Arch ______
83. Gill Raker Len. ______
84. Gill Raker Space ______
85. Pyloric Caeca ______
86. Vertebra 44+0+22=66
87. Physical Condition
88. ______
89. Vomer Width - 6.2 mm
90. Palatine Len - 14.8
91. Teeth P=12/13, V=2
92. Food ______
93. ______
94. ______
95. ______

1. **Specimen** 1279
2. Area Oliktok Poin
3. **Species** Arctic Cisco
4. Date 04/09/88
5. Capture Depth - 1m
6. Sex/Condition M 6
7. Scale Card ____
8. **Scale#** ____
9. Weight (g) 880
10. Fork Length 418 mm
11. Standard Length 388 mm
12. Mid-Eye Length ____
13. Rear Obit Len. ____
14. Total Length 456 mm
15. Body Length ____
16. Head Length 74.0 mm
17. Maxillary **Len.** 20.2 mm X 7.4
18. Maxillary Depth ____
19. Lower Jaw Len. 29.6 mm
20. Eye Diameter 13.2 mm
21. Obit Length 15.8 mm
22. Snout-Nostril 16.1 mm
23. Snout-Maxillary ____
24. Snout-Anterior Obit Length ____
25. **Snout-Occip** ____
26. Snout-Dorsal 185.8 mm
27. Snout-Adipose 327 mm
28. Snout-Pectoral ____
29. Snout-Pelvic ____
30. Snout-Anal 303 mm
31. Dorsal-Adipose ____
32. Pectoral-Pelvic ____
33. Pelvic-Anal ____
34. Pelvic **Caudal** ____
35. Dorsal **Caudal** Length ____
36. Vental **Caudal** Length ____
37. MAx. Extends - mideye
38. Mid-Eye Depth ____
39. Occiput Depth ____
40. Dorsal Fin Depth ____
41. **Caudal Peduncle Depth** 28.1 mm
42. Interorbital Width 21.7 mm
43. Mid-eye Width ____
44. Occiput Width ____
45. Body Width 93.0 mm
46. **Caudal Peduncle** Width ____
47. Circumference ____
48. Dorsal Fin Length ____
49. Dorsal Height (anterior/ posterior) ____
50. Adipose Base Length ____
51. Adipose Height 51.0 mm
52. Adipose Length ____
53. **Caudal** Fin Length (minimum/maximum) ____
54. Pectoral **Length** 47.6 mm
55. Pelvic Length ____
56. Anal Fin Length ____
57. Anal Height (anterior/ posterior) ____
58. Dorsal Fin **Rays** (3) 12 = 15
59. **Caudal** Rays (forked) 17
60. Pectoral Rays 17
61. Pelvic Rays 13
62. Anal Rays (2) 12 = 14
63. InOrbit Shape - Convex
64. ____
65. ____
66. Liver Weight ____
67. Gonad Weight ____
68. Egg Number ____
69. Egg Diameter ____
70. Pores, Lateral Line 98 + 1 C
71. Pores, **Std.Len.** ____
72. Scales, Lateral Line ____
73. Scales **(1st** power above L.L.)
74. ScalesrOccip. ____
75. Scales, Dorsal 11
76. Scales, Ventral 11
77. Scales, **Supra-**pelvic ____
78. Scales around **Caudal Peduncle** ____
79. **Branchiostegals** 8/9
80. Pores, Lower Jaw ____
81. Gill Rakers 1st Arch 15+1+24 = 40
82. Gill Rakers, 2nd Arch 19+1+27 = 47
83. Gill Raker Len. 12.2 mm
84. Gill Raker Space ____
85. **Pyloric** Caeca 129
86. Vertebra 35 + 8 ● Zz.&5
87. Physical Condition ____
88. Pseudobranchia - 18
89. Gill slit 4th - 16.3 mm
90. Vomer Width . 0
91. Palatine Len - 0
92. Food ____
93. ____
94. ____
95. ____

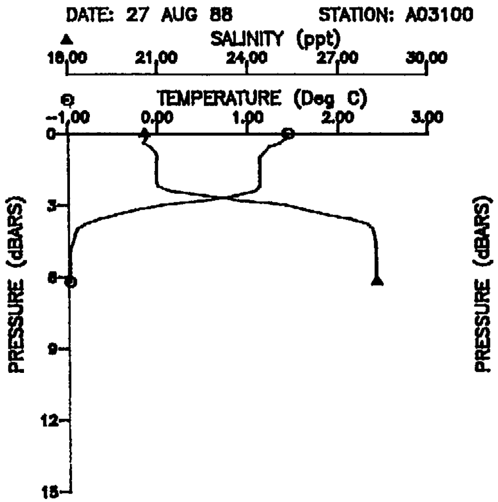
1. Specimen 1280
2. Area Oliktok Pt
3. Species Rainbow Smelt
4. Date 04/09/88
5. Capture Depth - 1m
6. Sex/Condition F2
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 252 mm
11. Standard Length 231.5mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 271.5mm
15. Body Length
16. Head Length 54.3 mm
17. Maxillary Len. 21.9mm
18. Maxillary Depth
19. Lower Jaw Len. 29.0 mm
20. Eye Diameter 10.1 mm
21. Obit Length 13.4 mm
22. Snout-Nostril 15.0 mm
23, Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal
27, Snout-Adipose
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 190.3 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Max. Extends - Rear Eye
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 12.3 mm
42. Interorbital Width 12.0 mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 40.2 mm
46. Caudal Peduncle Width 114.3 mm
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 36.7mm
55. Pelvic Length 32.0 mm
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Rays 12
59. Caudal Rays (forked) 16
60. Pectoral Rays 12
61. Pelvic Rays 8
62. Anal Rays 15
63. In Orbit Shape. Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 21/19
71. Pores, Std.Len.
72, Scales, Lateral Line 66
73. Scales (1st power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal 8
76, Scales, Ventral 9
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 7/7
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 9+1+20 = 30
82. Gill Rakers, 2nd Arch 2+1+19 = 28
83. Gill Raker Len. 7.2 mm
84. Gill Raker Space
85. Pyloric Caeca 6
86. Vertebra 43+0+22=65
87. Physical Condition
88. Pseudobranchia - 14
89. Gill S 1st 4th 11 mm
90. Vomer Width - 5.1 mm
91. Palatine Width - 15.8 mm
92. Food
93. Teeth V=3, P. 13/1
94.
95.

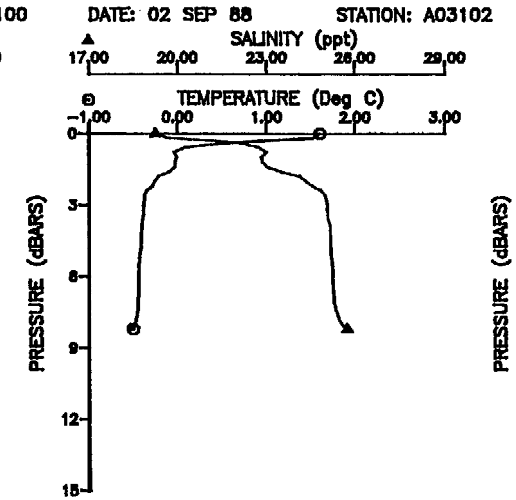
1. Specimen 1281
2. Area Oliktok oint
3. Species Bread Whitefish
4. Date 04/09/88
5. Capture Depth 1m
6. Sex/Condition M2
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 427.5 mm
11. Standard Length 397 mm
12. Mid-Eye Length
13, Rear Obit Len.
14. Total Length 473 mm
15. Body Length
16. Head Length 73.9 mm
17. Maxillary Len. ?.? x 8.6 mm
18. Maxillary Depth
19, Lower Jaw Len. 22.5 mm
20. Eye Diameter 13.1 mm
21. Obit Length 19.2 mm
22. Snout-Nostril /8.7 mm
23. Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 179.2 mm
27. Snout-Adipose 329 mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 314 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37, Max Extends Front Orbit
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 32.7 mm
42. Interorbital Width z~qM-
43. Mid-eye Width
44. Occiput Width
45. Body Width 87.2 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 65.5 mm
55. Pelvic Length 62.? mm
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Rays 15
59. Caudal Rays (forked) 17
60. Pectoral Rays 18
61. Pelvic Rays 11
62. Anal Rays 15
63. In Orbit Shape - Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 95+2 : 97
71. Pores, Std.Len.
72. Scales, Lateral Line 97
73. Scales (lst power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal 11
76. Scales, Ventral 9
77, Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 8/8
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 8+1+13=22
82. Gill Rakers, 2nd Arch 6+1+11 = 18
83. Gill Raker Len. 3.5 mm
84. Gill Raker Space
85. Pyloric Caeca 178
86. Vertebra 37+5+20= 62
87. Physical Condition
88. Pseudobranchia -20
89. Vomer Width - 0
90. Palatine L. . 0
91.
92. Food
93.
94.
95.

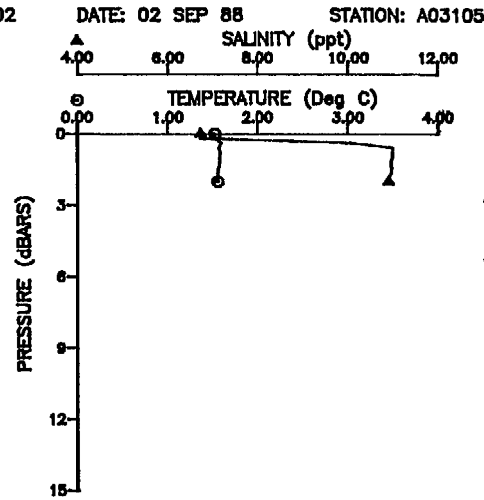
1. Specimen 1282
2. Area Oliktok Point
3. Species Least Cisco
4. Date 04/09/88
5. Capture Depth - 1m
6. Sex/Condition F2
7. Scale Card
8. Scale#
9. Weight (g)
10. Fork Length 313 mm
11. Standard Length 286mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 345mm
15, Body Length
16. Head Length 54.3mm
17. Maxillary Len. 16.2 mm x 6.0mm
18. Maxillary Depth
19. Lower Jaw Len. 25.0 mm
20. Eye Diameter 12.3 mm
21, Obit Length 14.8 mm
22, Snout-Nostril 10.8m
23. Snout-Maxillary
24. Snout-Anterior Obit Length
25. Snout-Occip
26. Snout-Dorsal 127.7 mm
27. Snout-Adipose 238.6mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 218 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33. Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Max Extends - mideye
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 23.7mm
42. Interorbital Width 12.5mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 69.7 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 50.3mm
55. Pelvic Length 50.4mm
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Rays 15
59. Caudal Rays (forked) 16
60. Pectoral Rays 14
61. Pelvic Rays 11
62. Anal Rays 16
63. In Orbit Shape - Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 74+1
71. Pores, Std.Len.
72. Scales, Lateral Line 76
73. Scales (1st power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal 10
76. Scales, Ventral 8
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 8/8
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 14+1+39=54
82. Gill Rakers, 2nd Arch 16+1+29
83. Gill Raker Len. 10.2mm
84. Gill Raker Space
85. Pyloric Caeca 74
86. Vertebra 36+4+22=62
87. Physical Condition
88. Pseudobranchii - 23
89. Gill Slit 4th - 11.2 mm
90. Vomer Wid th 0
91. Pala Has Len 0
92. Food
93.
94.
95.

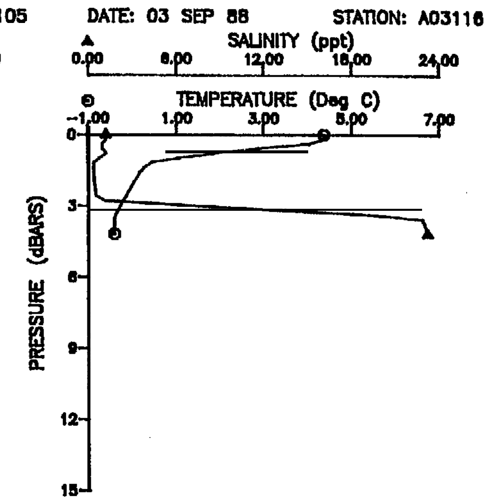
1. Specimen 1283
2. Area Oliktok Point
3. Species Least Cisco
4. Date 06/09/88
5.
6. Sex/Condition ♀
7. Scale Card
8. Scale#
9. Weight (g) 670
10. Fork Length 381mm
11. Standard Length 347.5mm
12. Mid-Eye Length
13. Rear Obit Len.
14. Total Length 415.5 mm
15, Body Length
16. Head Length 67.S mm
17. Maxillary Len. 19.2X7.4
18. Maxillary Depth
19. Lower Jaw Len. 27.4 mm
20, Eye Diameter 1a.0 mm
21, Obit Length 1?.4 mm
22, Snout-Nostril 16.0 mm
23. Snout-Maxillary
24. Snout-Anterior Obit Length
25, Snout-Occip
26. Snout-Dorsal 154.3 mm
27. Snout-Adipose 285 mm
28. Snout-Pectoral
29. Snout-Pelvic
30. Snout-Anal 268 mm
31. Dorsal-Adipose
32. Pectoral-Pelvic
33, Pelvic-Anal
34. Pelvic Caudal
35. Dorsal Caudal Length
36. Vental Caudal Length
37. Max Extends - mideye
38. Mid-Eye Depth
39. Occiput Depth
40. Dorsal Fin Depth
41. Caudal Peduncle Depth 26.7 mm
42. Interorbital Width 15.7 mm
43. Mid-eye Width
44. Occiput Width
45. Body Width 80 mm
46. Caudal Peduncle Width
47. Circumference
48. Dorsal Fin Length
49. Dorsal Height (anterior/ posterior)
50. Adipose Base Length
51. Adipose Height
52. Adipose Length
53. Caudal Fin Length (minimum/maximum)
54. Pectoral Length 57.6mm
55. Pelvic Length 51.6mm
56. Anal Fin Length
57. Anal Height (anterior/ posterior)
58. Dorsal Fin Rays 15
59. Caudal Rays (forked) 17
60. Pectoral Rays 17
61. Pelvic Rays 12
62. Anal Rays /7
63. InOrbit Shape Convex
64.
65.
66. Liver Weight
67. Gonad Weight
68. Egg Number
69. Egg Diameter
70. Pores, Lateral Line 84 + 2
71. Pores, Std.Len.
72. Scales, Lateral Line 07
73. Scales (1st power above L.L.)
74. Scales,Occip.
75. Scales, Dorsal 10
76. Scales, Ventral 9
77. Scales, Supra-pelvic
78. Scales around Caudal Peduncle
79. Branchiostegals 9/9
80. Pores, Lower Jaw
81. Gill Rakers 1st Arch 17+1+30= 48
82. Gill Rakers, 2nd Arch 18+1+30=49
83. Gill Raker Len. 9.0mm
84. Gill Raker Space
85. Pyloric Caeca 81
86. Vertebra 35+6+22= 63
87. Physical Condition
88. Pseudo branchia ++
89. Gill Slit 4th - 14.2mm
90. Vomer Width - 0
91. Palatine Len 0
92. Food
93. Condition spo He d
94.
95.

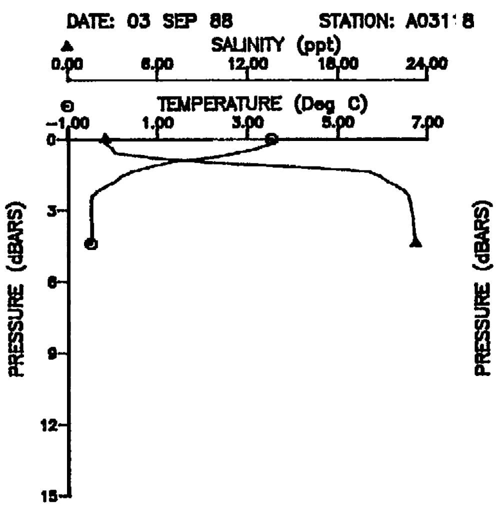
Appendix C
CTD Station Data

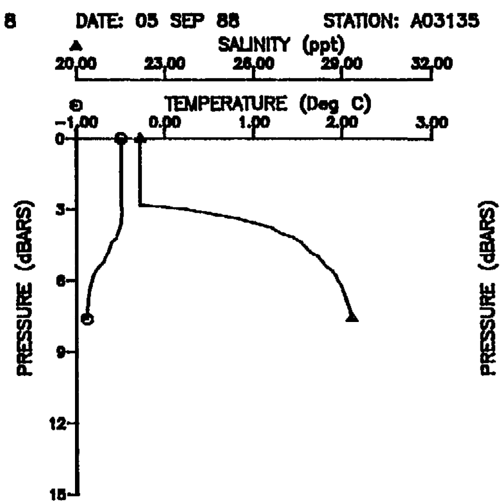

DATE: 27 AUG 88
STATION: A03100
SALINITY (ppt)
18.00 21.00 24.00 27.00 30.00
TEMPERATURE (Deg C)
-1.00 0.00 1.00 2.00 3.00
PRESSURE (dBARS)
0 3 6 9 12 15

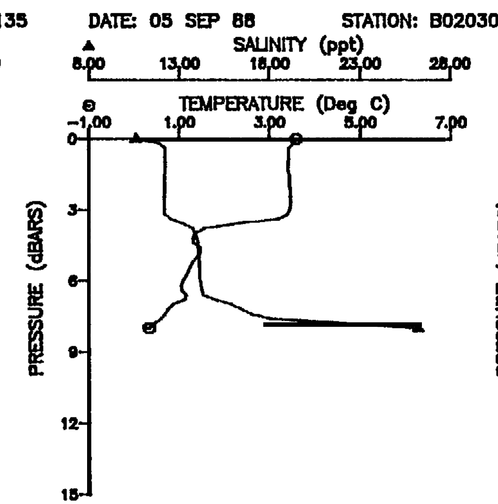

DATE: 02 SEP 88
STATION: A03102
SALINITY (ppt)
17.00 20.00 23.00 26.00 29.00
TEMPERATURE (Deg C)
-1.00 0.00 1.00 2.00 3.00
PRESSURE (dBARS)
0 3 6 9 12 15

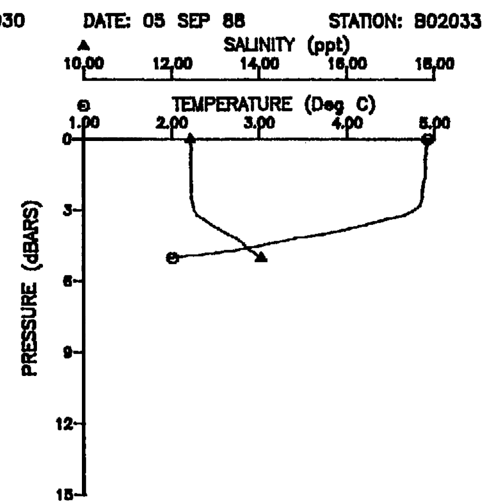

DATE: 02 SEP 88
STATION: A03105
SALINITY (ppt)
4.00 6.00 8.00 10.00 12.00
TEMPERATURE (Deg C)
0.00 1.00 2.00 3.00 4.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 03 SEP 88
STATION: A03116
SALINITY (ppt)
0.00 6.00 12.00 18.00 24.00
TEMPERATURE (Deg C)
-1.00 1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15

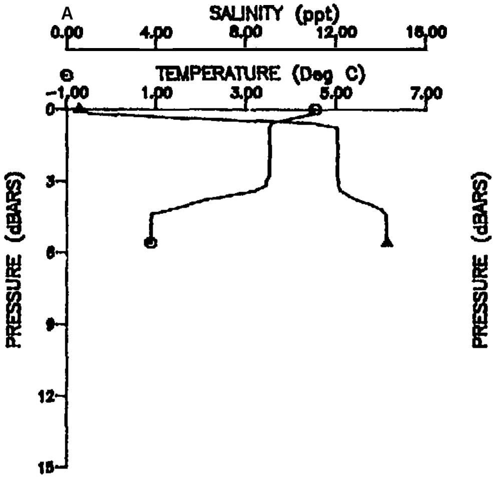

DATE: 03 SEP 88
STATION: A031'8
SALINITY (ppt)
0.00 6.00 12.00 18.00 24.00
TEMPERATURE (Deg C)
-1.00 1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 05 SEP 88
STATION: A03135
SALINITY (ppt)
20.00 23.00 26.00 29.00 32.00
TEMPERATURE (Deg C)
-1.00 0.00 1.00 2.00 3.00
PRESSURE (dBARS)
0 3 6 9 12 15

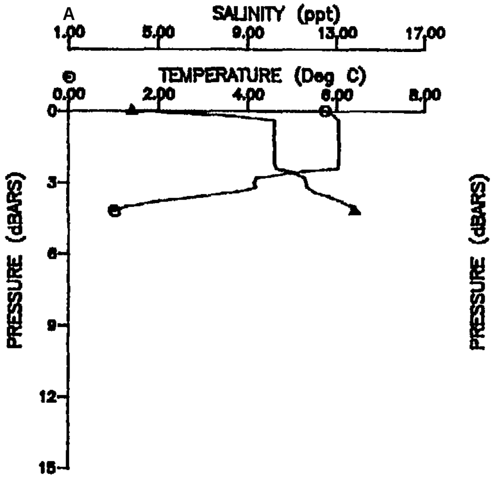

DATE: 05 SEP 88
STATION: B02030
SALINITY (ppt)
8.00 13.00 18.00 23.00 28.00
TEMPERATURE (Deg C)
-1.00 1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 05 SEP 88
STATION: B02033
SALINITY (ppt)
10.00 12.00 14.00 16.00 18.00
TEMPERATURE (Deg C)
1.00 2.00 3.00 4.00 5.00
PRESSURE (dBARS)
0 3 6 9 12 15

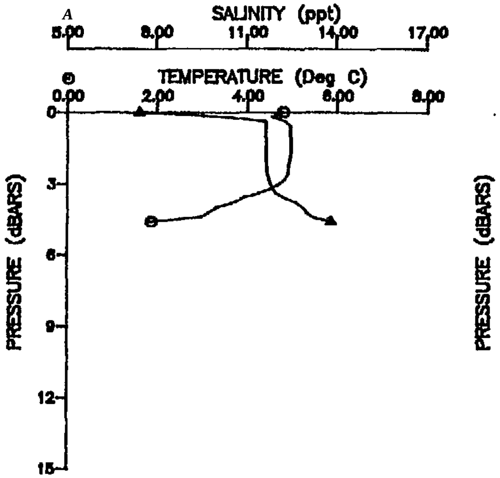
DATE: 05 SEP 88 STATION: B02035



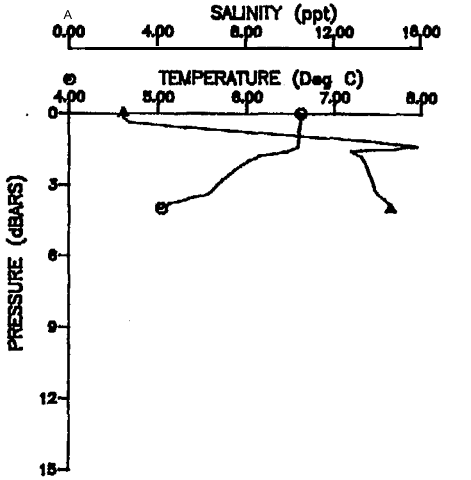
DATE: 06 AUG S5 STATION: B02037



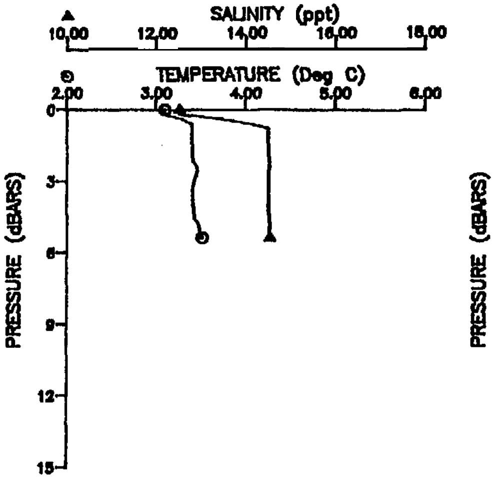
DATE 08 AUG SS STATION S02039



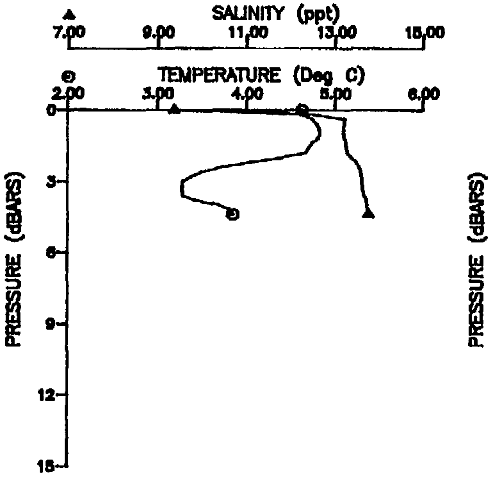
DATE: 04 AUG 88 STATION: B03020



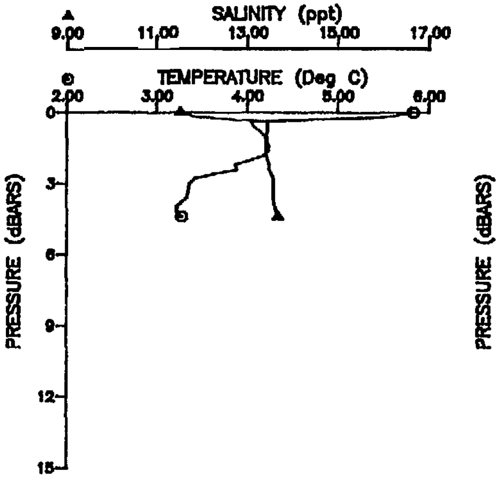
DATE: 04 AUG 88 STATION: B03022



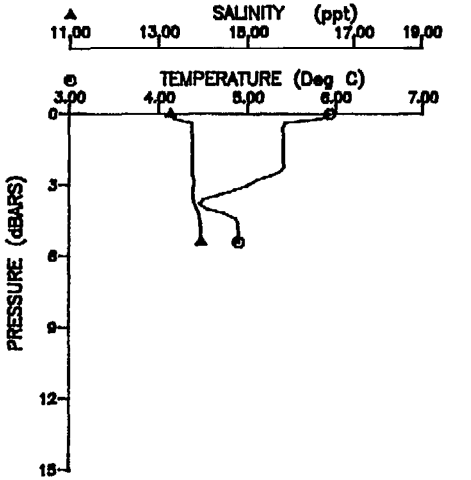
DATE: 09 AUG 88 STATION: B03041

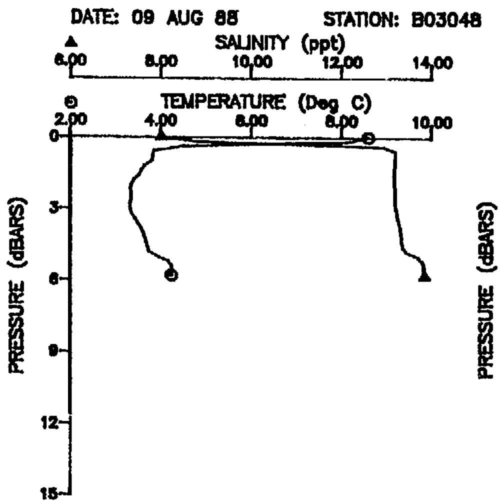


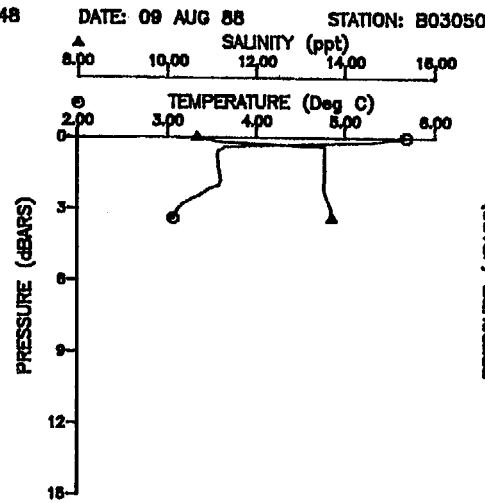
DATE: 09 AUG 88 STATION: B03043



DATE: OS AUG 88 STATION: B03048




DATE: 09 AUG 88
STATION: B03048
SALINITY (ppt)
6.00 8.00 10.00 12.00 14.00
TEMPERATURE (Deg C)
2.00 4.00 6.00 8.00 10.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 09 AUG 88
STATION: B03050
SALINITY (ppt)
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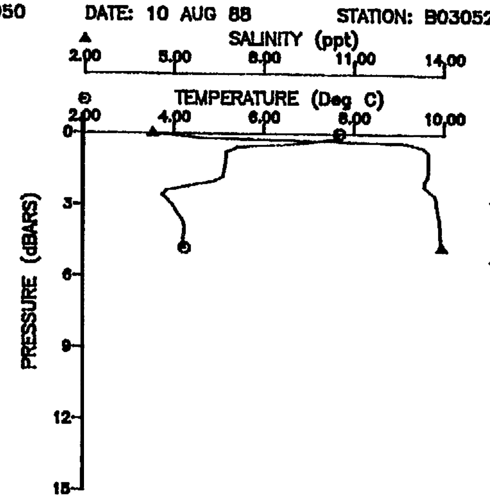
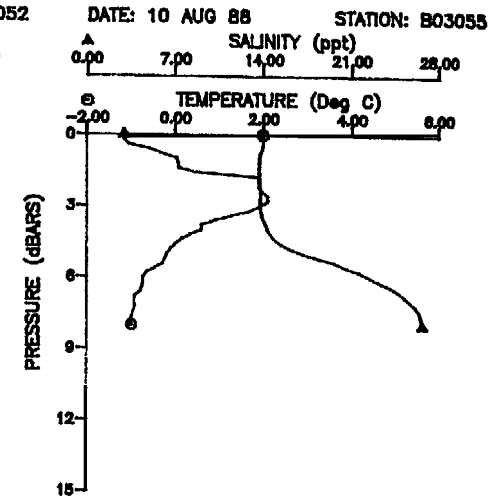
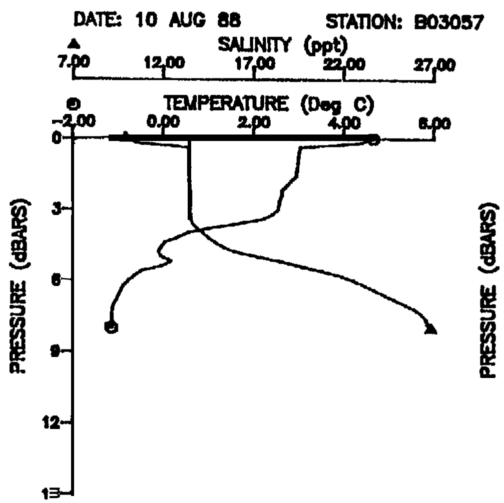
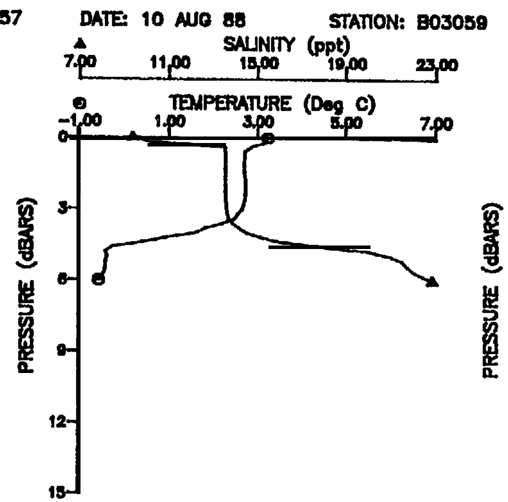
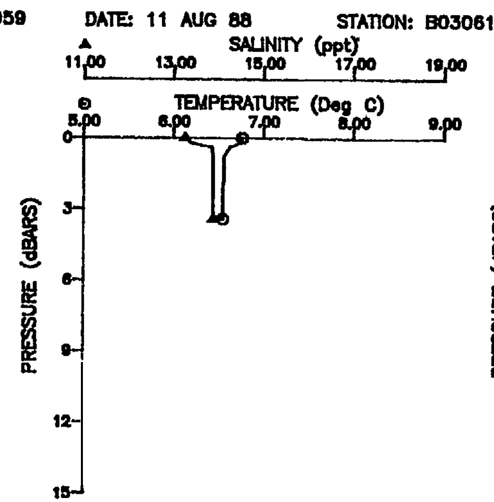
TEMPERATURE (Deg C)
2.00 3.00 4.00 5.00 6.00
PRESSURE (dBARS)
0 3 6 9 12 15

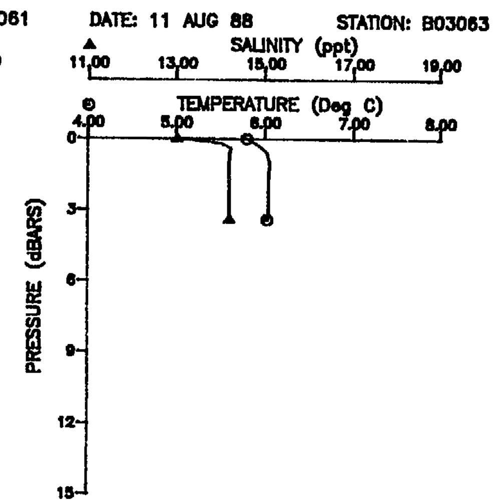

DATE: 10 AUG 88
STATION: B03052
SALINITY (ppt)
2.00 5.00 8.00 11.00 14.00
TEMPERATURE (Deg C)
2.00 4.00 6.00 8.00 10.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 10 AUG 88
STATION: B03055
SALINITY (ppt)
0.00 7.00 14.00 21.00 28.00
TEMPERATURE (Deg C)
-2.00 0.00 2.00 4.00 6.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 10 AUG 88
STATION: B03057
SALINITY (ppt)
7.00 12.00 17.00 22.00 27.00
TEMPERATURE (Deg C)
-2.00 0.00 2.00 4.00 6.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 10 AUG 88
STATION: B03059
SALINITY (ppt)
7.00 11.00 15.00 19.00 23.00
TEMPERATURE (Deg C)
-1.00 1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 11 AUG 88
STATION: B03061
SALINITY (ppt)
11.00 13.00 15.00 17.00 19.00
TEMPERATURE (Deg C)
5.00 6.00 7.00 8.00 9.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 11 AUG 88
STATION: B03063
SALINITY (ppt)
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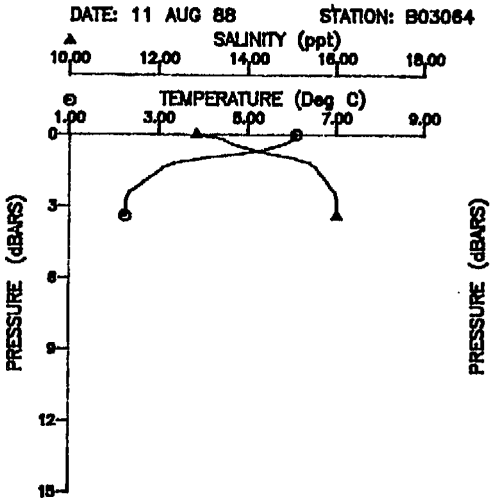
TEMPERATURE (Deg C)
4.00 5.00 6.00 7.00 8.00
PRESSURE (dBARS)
0 3 6 9 12 15



DATE: 11 AUG 88
STATION: B03064
SALINITY (ppt)
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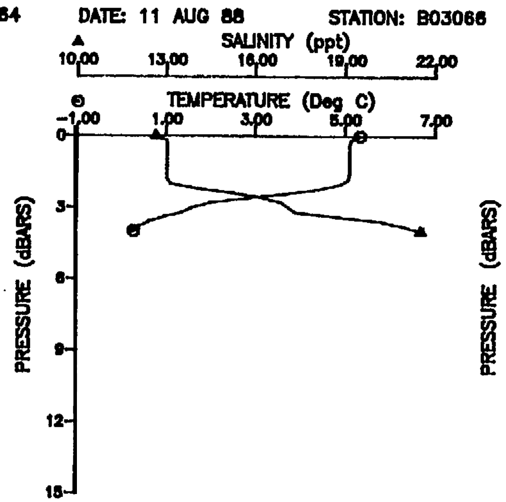
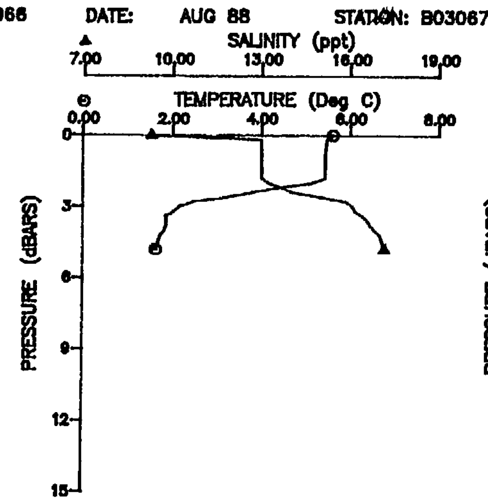
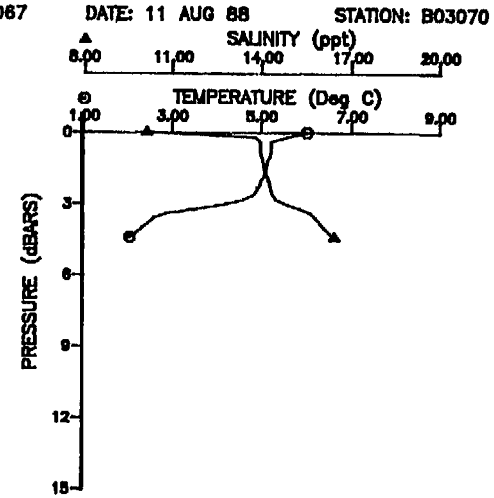
TEMPERATURE (Deg C)
1.00 3.00 5.00 7.00 9.00
PRESSURE (dBARS)
0 3 6 9 12 15



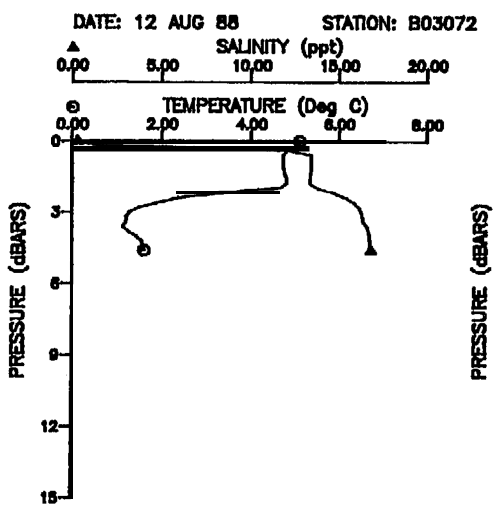
DATE: 11 AUG 88
STATION: B03066
SALINITY (ppt)
10.00 13.00 16.00 19.00 22.00
TEMPERATURE (Deg C)
-1.00 1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15



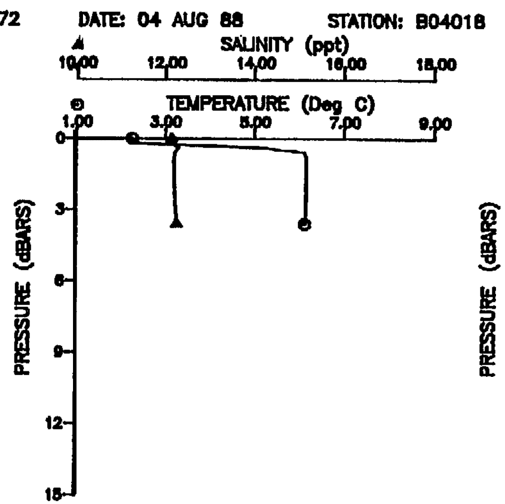
DATE: AUG 88
STATION: B03067
SALINITY (ppt)
7.00 10.00 13.00 16.00 19.00
TEMPERATURE (Deg C)
0.00 2.00 4.00 6.00 8.00
PRESSURE (dBARS)
0 3 6 9 12 15



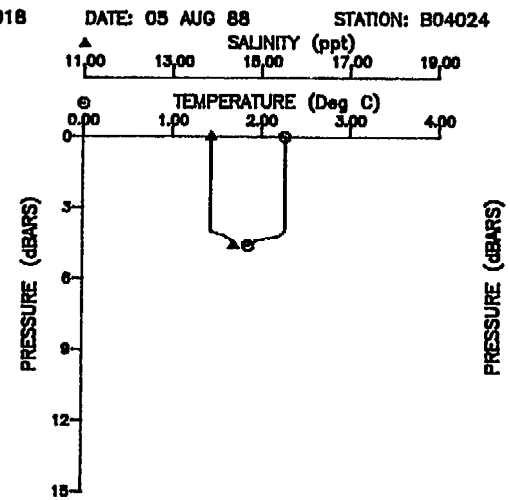
DATE: 11 AUG 88
STATION: B03070
SALINITY (ppt)
8.00 11.00 14.00 17.00 20.00
TEMPERATURE (Deg C)
1.00 3.00 5.00 7.00 9.00
PRESSURE (dBARS)
0 3 6 9 12 15



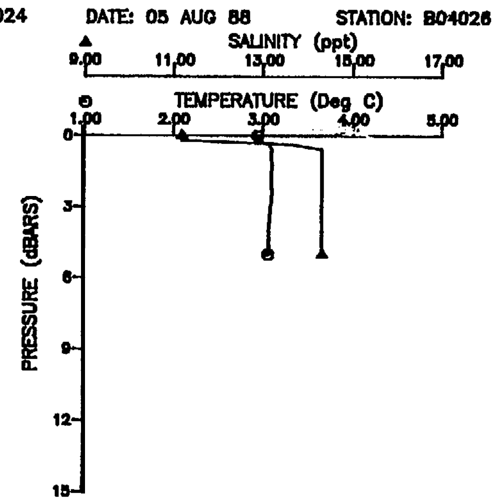
DATE: 12 AUG 88
STATION: B03072
SALINITY (ppt)
0.00 5.00 10.00 15.00 20.00
TEMPERATURE (Deg C)
0.00 2.00 4.00 6.00 8.00
PRESSURE (dBARS)
0 3 6 9 12 15



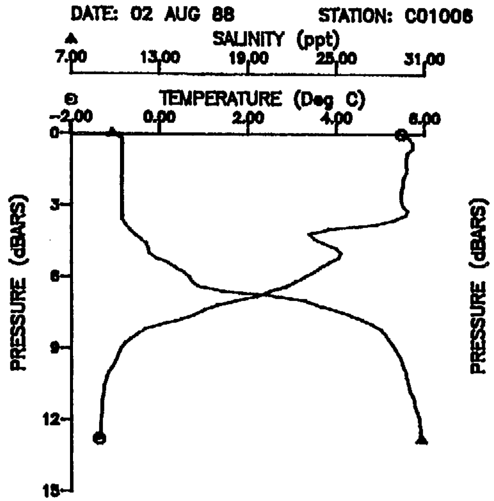
DATE: 04 AUG 88
STATION: B04018
SALINITY (ppt)
10.00 12.00 14.00 16.00 18.00
TEMPERATURE (Deg C)
1.00 3.00 5.00 7.00 9.00
PRESSURE (dBARS)
0 3 6 9 12 15

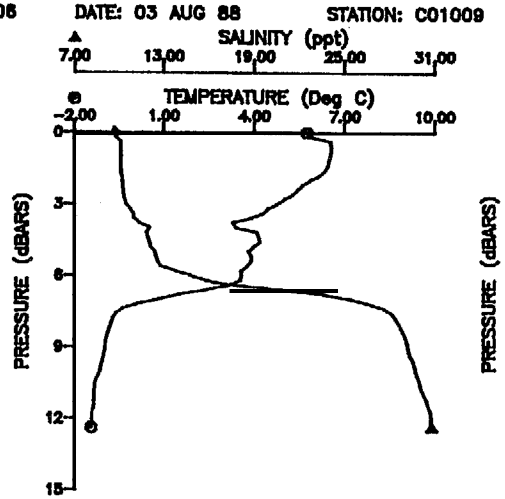


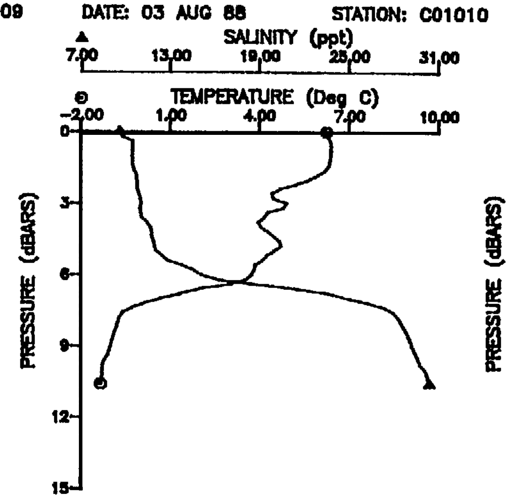
DATE: 05 AUG 88
STATION: B04024
SALINITY (ppt)
11.00 13.00 15.00 17.00 19.00
TEMPERATURE (Deg C)
0.00 1.00 2.00 3.00 4.00
PRESSURE (dBARS)
0 3 6 9 12 15

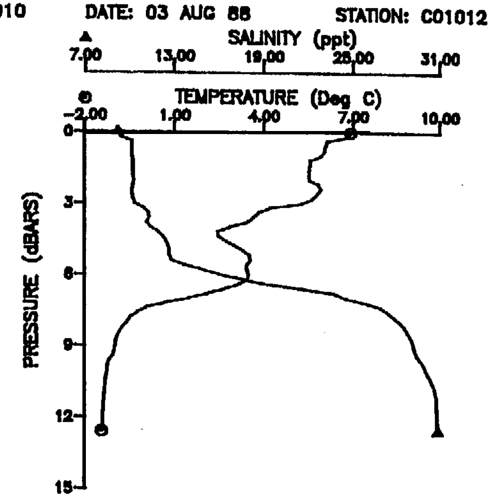


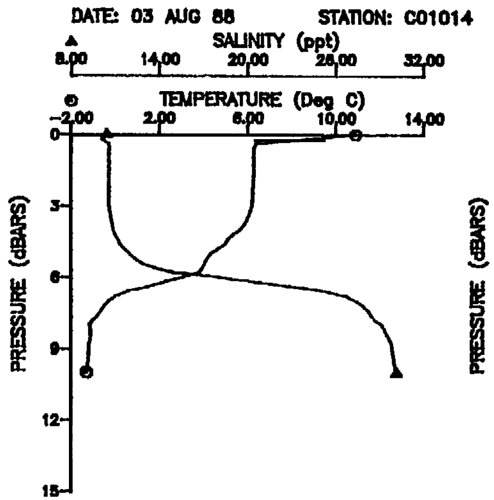
DATE: 05 AUG 88
STATION: B04026
SALINITY (ppt)
9.00 11.00 13.00 15.00 17.00
TEMPERATURE (Deg C)
1.00 2.00 3.00 4.00 5.00
PRESSURE (dBARS)
0 3 6 9 12 15

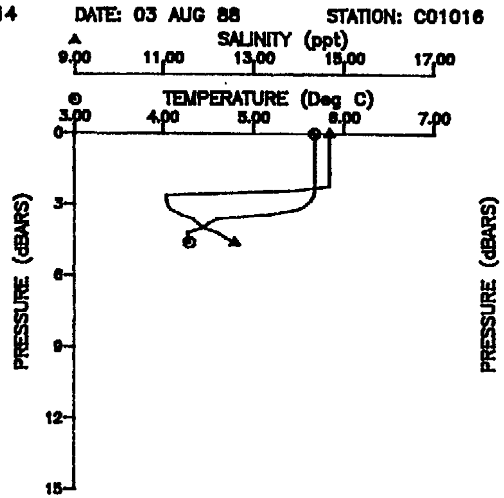

DATE: 02 AUG 88
STATION: C01006
SALINITY (ppt)
7.00 13.00 19.00 25.00 31.00
TEMPERATURE (Deg C)
-2.00 0.00 2.00 4.00 6.00
PRESSURE (dBARS)
0 3 6 9 12 15

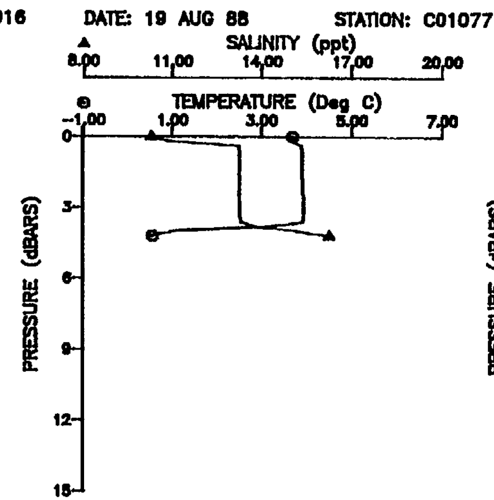

DATE: 03 AUG 88
STATION: C01009
SALINITY (ppt)
7.00 13.00 19.00 25.00 31.00
TEMPERATURE (Deg C)
-2.00 1.00 4.00 7.00 10.00
PRESSURE (dBARS)
0 3 6 9 12 15

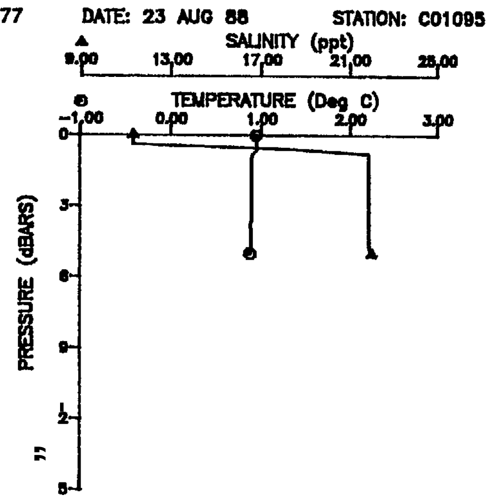

DATE: 03 AUG 88
STATION: C01010
SALINITY (ppt)
7.00 13.00 19.00 25.00 31.00
TEMPERATURE (Deg C)
-2.00 1.00 4.00 7.00 10.00
PRESSURE (dBARS)
0 3 6 9 12 15

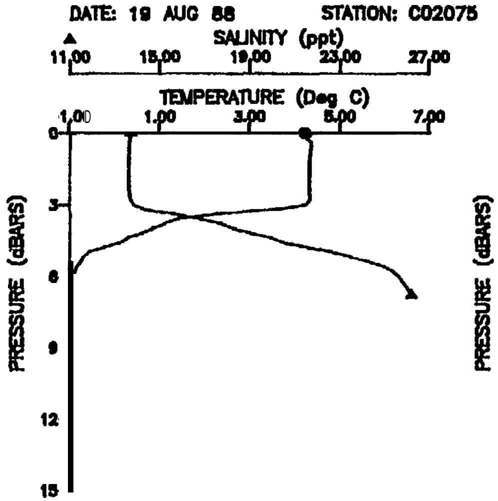

DATE: 03 AUG 88
STATION: C01012
SALINITY (ppt)
7.00 13.00 19.00 25.00 31.00
TEMPERATURE (Deg C)
-2.00 1.00 4.00 7.00 10.00
PRESSURE (dBARS)
0 3 6 9 12 15

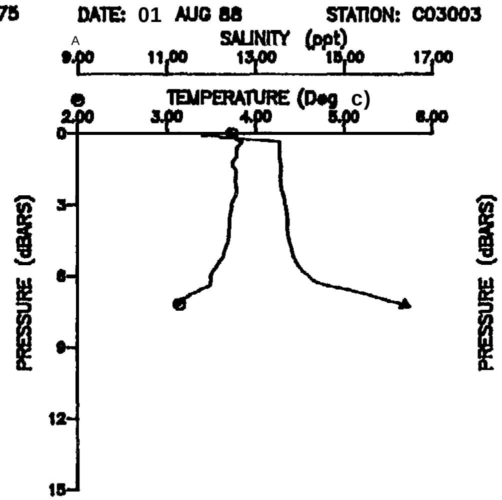

DATE: 03 AUG 88
STATION: C01014
SALINITY (ppt)
8.00 14.00 20.00 26.00 32.00
TEMPERATURE (Deg C)
-2.00 2.00 6.00 10.00 14.00
PRESSURE (dBARS)
0 3 6 9 12 15

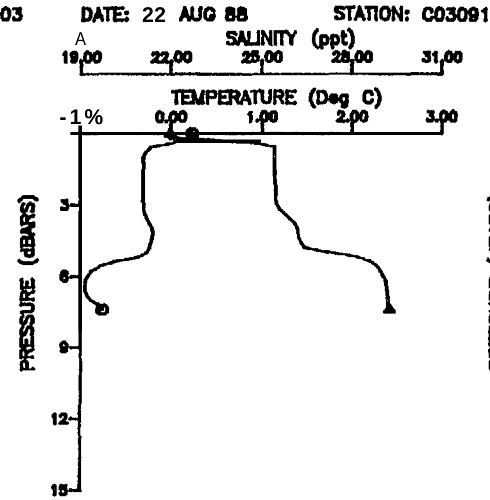

DATE: 03 AUG 88
STATION: C01016
SALINITY (ppt)
9.00 11.00 13.00 15.00 17.00
TEMPERATURE (Deg C)
3.00 4.00 5.00 6.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15

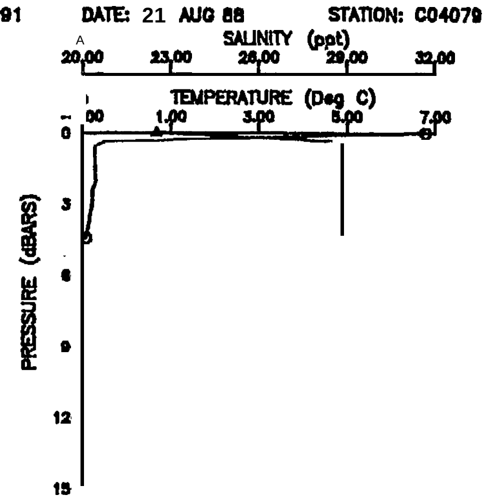

DATE: 19 AUG 88
STATION: C01077
SALINITY (ppt)
8.00 11.00 14.00 17.00 20.00
TEMPERATURE (Deg C)
-1.00 1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15

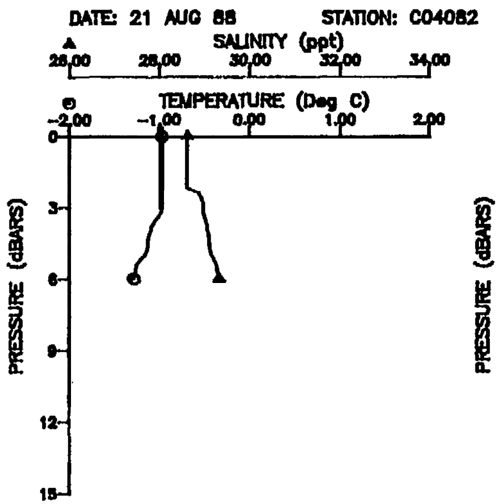

DATE: 23 AUG 88
STATION: C01095
SALINITY (ppt)
9.00 13.00 17.00 21.00 25.00
TEMPERATURE (Deg C)
-1.00 0.00 1.00 2.00 3.00
PRESSURE (dBARS)
0 3 6 9

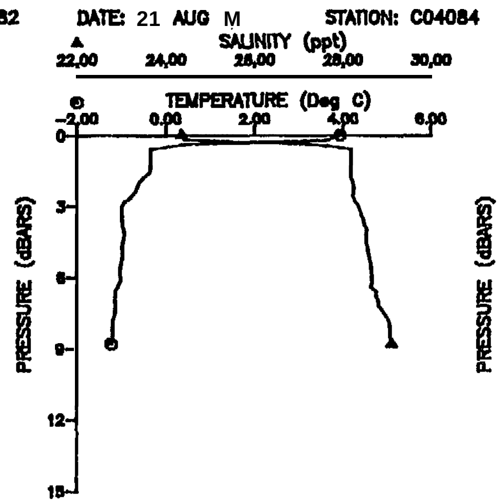

DATE: 19 AUG 88 STATION: C02075
SALINITY (ppt)
11.00 15.00 19.00 23.00 27.00
TEMPERATURE (Deg C)
1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15

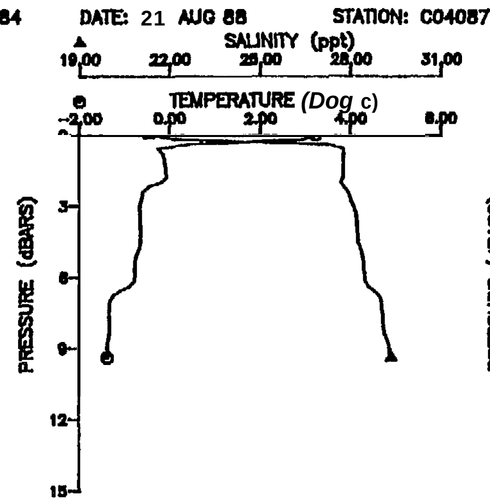

DATE: 01 AUG 88 STATION: C03003
SALINITY (ppt)
9.00 11.00 13.00 15.00 17.00
TEMPERATURE (Deg C)
2.00 3.00 4.00 5.00 6.00
PRESSURE (dBARS)
0 3 6 9 12 15

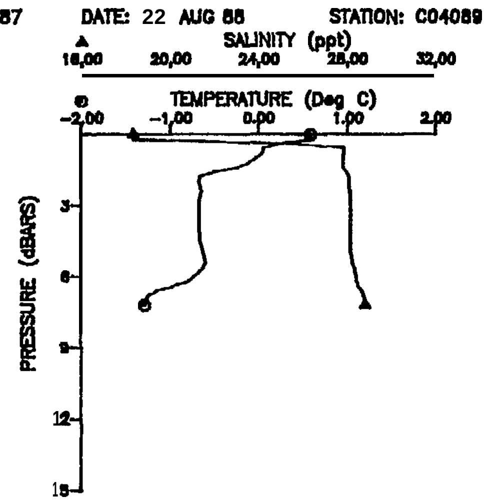

DATE: 22 AUG 88 STATION: C03091
SALINITY (ppt)
19.00 22.00 25.00 28.00 31.00
TEMPERATURE (Deg C)
0.00 1.00 2.00 3.00
PRESSURE (dBARS)
0 3 6 9 12 15

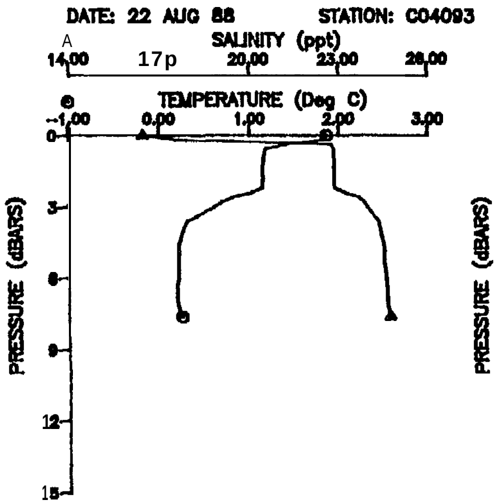

DATE: 21 AUG 88 STATION: C04079
SALINITY (ppt)
20.00 23.00 26.00 29.00 32.00
TEMPERATURE (Deg C)
1.00 3.00 5.00 7.00
PRESSURE (dBARS)
0 3 6 9 12 15

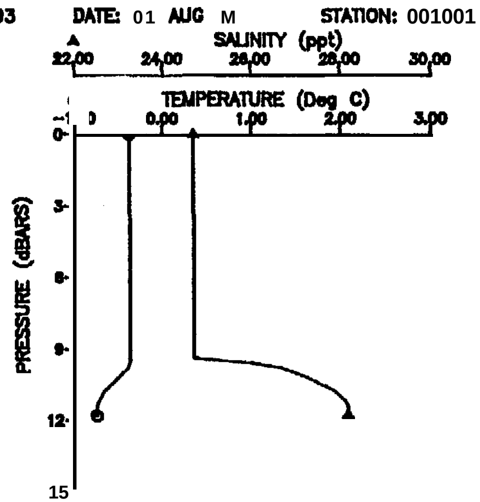

DATE: 21 AUG 88 STATION: C04082
SALINITY (ppt)
26.00 28.00 30.00 32.00 34.00
TEMPERATURE (Deg C)
-2.00 -1.00 0.00 1.00 2.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 21 AUG STATION: C04084
SALINITY (ppt)
22.00 24.00 26.00 28.00 30.00
TEMPERATURE (Deg C)
-2.00 0.00 2.00 4.00 6.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 21 AUG 88 STATION: C04087
SALINITY (ppt)
19.00 22.00 25.00 28.00 31.00
TEMPERATURE (Deg C)
-2.00 0.00 2.00 4.00 6.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 22 AUG 88 STATION: C04089
SALINITY (ppt)
16.00 20.00 24.00 28.00 32.00
TEMPERATURE (Deg C)
-2.00 -1.00 0.00 1.00 2.00
PRESSURE (dBARS)
0 3 6 9 12 15


DATE: 22 AUG 88
STATION: C04093
SALINITY (ppt)
14.00
17p
20.00
23.00
26.00
TEMPERATURE (Deg C)
-1.00
0.00
1.00
2.00
3.00
PRESSURE (dBARS)
0
3
6
9
12
15


DATE: 01 AUG M
STATION: 001001
SALINITY (ppt)
22.00
24.00
26.00
28.00
30.00
TEMPERATURE (Deg C)
0.00
1.00
2.00
3.00
PRESSURE (dBARS)
0
3
6
9
12
15

Appendix D
Seine and Gillnet Fishing Locations

Station	Date	Gear	Fishing Location LAT (N)	LONG (W)	NAV
D01002	8-01	BN	70 10.4	143 41.8	LC
C01005	8-02	BN	70 9.3	145 38.9	LC
C01007	8-02	Ps	70 9.3	145 37.2	LC
C01008	8-02	Ps	70 9.3	145 37.2	LC
Colon	8-02	Ps	70 9.0	145 38.2	LC
C01013	8-02	Ps	70 8.9	145 38.5	LC
C01015	8-02	Ps	70 8.5	145 38.5	LC
C01017	8-02	Ps	70 7.5	145 40.1	LC
B04019	8-04	Ps	70 12.6	146 27.6	LC
B03021	8-04	Ps	70 11.5	146 52.3	LC
B03023	8-04	Ps	70 11.8	146 51.6	LC
B04025	8-04	BN	70 15.0	146 51.0	LC
B04027	8-04	Ps	70 13.1	147 00.2	LC
B04028	8-04	Ps	70 13.1	147 00.5	LC
B04029	8-04	Ps	70 12.9	147 00.9	LC
B02031	8-05	Ps	70 22.5	147 38.4	LC
B02032	8-05	Ps	70 22.5	147 38.4	LC
B02034	8-05	Ps	70 19.7	147 39.1	LC
B02036	8-05	Ps	70 20.4	147 43.2	LC
B02038	8-05	Ps	70 20.8	147 48.9	LC
B02040	8-05	Ps	70 20.0	147 45.3	LC
B03042	8-09	GN	70 11.6	146 58.4	LC
B03044	8-09	Ps	70 12.1	146 58.3	LC
B03046	8-09	Ps	70 12.0	147 03.0	LC
B03047	8-09	Ps	70 12.5	147 03.0	LC
B03049	8-09	Ps	70 15.4	147 06.2	LC
B03051	8-09	Ps	70 13.9	146 52.9	LC
B03053	8-09	GN	70 11.6	146 58.4	DR
B03054	8-09	GN	70 10.6	146 51.6	DR
B03056	8-10	BN	70 16.5	146 48.6	LC
B03058	8-10	Ps	70 16.9	146 46.3	LC
B03060	8-10	Ps	70 15.8	146 42.2	LC
B03062	8-10	GN	70 11.6	146 51.7	DR
B03065	8-11	GN	70 12.5	146 59.6	DR
B03068	8-11	Ps	70 13.3	146 56.2	LC
B03069	8-11	Ps	70 12.5	146 59.6	LC
B03071	8-11	Ps	70 12.9	147 01.4	LC
B03073	8-11	Ps	70 12.6	146 59.8	LC
B03074	8-11	GN	70 12.6	146 59.7	LC
C02075	8-18	Ps	70 03.5	145 18.4	SN
C01078	8-18	Ps	70 01.9	144 59.6	LC
C04080	8-21	Ps	69 56.6	144 32.0	SN
C04081	8-21	Ps	69 58.5	144 36.3	SN

C04083	**8-21**	**PS**	69	57.7	144	33.6	LC
C04085	**8-21**	**PS**	70	01.5	144	35.4	**LC**
C04086	**8-21**	BN	70	01.5	144	38.8	LC
C04088	**8-21**	**PS**	70	00.7	144	46.4	LC
C04090	**8-21**	Ps	69	58.8	144	46.8	**LC**
C03092	**8-22**	**PS**	70	00.9	144	03.2	LC
C04094	**8-22**	**PS**	70	00.6	144	49.6	**LC**
CO1096	**8-22**	**PS**	70	02.9	145	19.1	LC
CO1098	**8-22**	**PS**	70	06.0	145	33.8	LC
A03099	**8-26**	GN	70	33.1	**150**	08.8	DR
AO3101	**8-27**	**PS**	70	34.0	150	18.3	LC
AO3102	**8-28**	**GN**	70	33.2	150	11.5	DR
AO3103	**9-01**	**GN**	70	30.9	149	53.8	DR
AO3104	**9-02**	**GN**	70	30.9	149	52.0	DR
AO3106	**9-02**	**GN**	70	30.8	149	52.0	DR
AO3107	**9-02**	**GN**	70	30.8	149	52.0	DR
AO3108	**9-02**	**GN**	70	30.8	149	52.0	DR
AO3109	**9-02**	**GN**	70	30.8	149	52.6	**DR**
AO3110	**9-02**	**GN**	**70**	**30.8**	**149**	**52.8**	**DR**
A03111	**9-02**	**GN**	**70**	**30.8**	**149**	**52.6**	**DR**
A03112	**9-02**	**GN**	**70**	**30.8**	**149**	**52.6**	**DR**
A03113	**9-02**	**GN**	**70**	**30.8**	**149**	**52.0**	**DR**
A03115	9-03	**BN**	70	33.4	150	17.5	LC
A03117	9-03	**PS**	70	33.1	150	15.2	LC
A03119	9-03	**PS**	70	32.8	150	14.1	**LC**
A03120	9-03	**GN**	70	30.7	149	52.7	DR
A03121	9-03	**GN**	70	30.7	149	52.5	DR
AO3125	9-04	**GN**	70	30.7	149	52.5	DR
AO3128	9-04	**GN**	70	30.7	149	52.7	DR
AO3129	9-04	**GN**	70	30.7	149	52.5	DR
AO3130	9-04	**GN**	70	30.7	149	52.5	DR
A03136	9-05	**BN**	70	34.3	149	34.4	**LC**
AO3138	9-05	**GN**	70	30.7	149	52.5	DR
AO3139	9-05	**GN**	70	30.7	149	52.5	DR
A03140	9-06	**GN**	70	30.7	149	52.5	**DR**
AO3141	9-06	**GN**	**70**	**30.7**	**149**	**52.5**	**DR**
AO3142	9-06	**GN**	**70**	**34.3**	**149**	**53.9**	**DR**
AO3143	9-06	**GN**	**70**	**30.7**	**149**	**52.5**	**DR**
AO3144	9-06	**GN**	**70**	**30.7**	**149**	**52.5**	**DR**
AO3154	9-06	**GN**	**70**	**34.5**	**149**	**53.9**	**DR**